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Dynamic networks. An interdisciplinary study of network organization in biological and human social systems

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Dynamic Networks. An interdisciplinary study of network organization in biological and human social systems.

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Abstract

This thesis is about a metaphor; it explores the idea that human organizations could be treated "as if" they behaved like biological systems. The thesis focuses on one biological metaphor in particular – the idea of a living *network.*

The thesis begins with an exploration of the philosophical background to my research. The development of rationalistic and reductionist approaches to systems enquiry is described, and the limitations of these approaches are discussed. This is followed by a discussion of non-linear, holistic and other approaches, including a newly emerging perspective known as Inclusionality. Communication is an important aspect of both human and biological systems, so I continue by examining established theories of communication, showing how they have influenced the way we understand communicative systems. A chapter is devoted to the subject of metaphor, which explains how in contemporary research, metaphor is treated not merely as a linguistic device, but as a *cognitive* tool that reflects how we make connections between ideas. Various metaphors for human organizations are discussed, including the network metaphor.

I deal with network theory itself in some detail, firstly exploring conventional network theory, which is concerned with networks that are *node* based, and secondly with the organization of natural biological networks which are quite different in form and are the products of autocatalytic *flow.* The concept of the "flow-form network" as a metaphor for human organizations is explored, and some of the methodological issues concerning the study of such networks are discussed.

The latter part of the thesis describes a practical study of a human organization, where communicative patterns were investigated. The study highlights how flow-form networks might be identified in human organizations, as well as the limitations that conventional methods of enquiry pose in such an investigation.

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Chapter 1 – Introduction

1.1 An intellectual journey

This thesis is a written account of an intellectual journey that I have made. In the autumn of 1999, as a recent biology graduate, I began formally researching links between biological systems and human organizations. Over the subsequent years I have explored many paths. These paths have led me to a wide variety of different topics and ideas. Some of the routes I took were hard to navigate, while others were well-trodden paths. Like the conduits within a natural network, my routes were not fixed. Indeed some of paths I chose turned out to be blind alleys, some took unexpected turns; others went only a certain distance before fading away, meaning I was faced with a choice: to turn back, or create a path of my own.

The experiences we have in our early years can have a formative effect on the directions that we take in later life. The research I have presented in this thesis could be viewed as a phase in a lifetime's intellectual journey. It would therefore be helpful to start this thesis with some account of my personal background, which explains how and why I became interested in my research topic in the first instance, and what motivated me to pursue it to its conclusion.

1.2 My origins in biology

I initially chose to study biology because, having grown up in the countryside, I loved the natural world. As a child I spent a great deal of time in the woods and fields that surrounded my parents' home, and developed a huge affinity for them. Home was a smallholding of about 20 acres, which was surrounded by a mixture of oak woodlands, grass meadows and heathland, so there was a huge variety of wildlife to see. I loved learning to identify and name the plants, insects and other animals that I encountered. I often collected and sketched the treasures that I found outside, and made journals containing notes about the animals and birds I had seen.

Later, as a teenager, when at school I began to make the choices in subject matter that would lead me to specialise in biology, I did so not so much because I loved science, but because I loved nature. Aged thirteen/fourteen, I wanted to be a garden designer, or a herbalist, or preferably both! I was fascinated with the idea of growing and using the things found in the natural world. I was avid in my quest to learn more; I think it was about that time that I began to collect books on studying nature. In terms of formal education, the obvious route was science. But while scientific study interested me, I saw it as a means to an end – at that time I enjoyed science lessons because they were the most direct way I could get to work with plants and animals at school.

Doing biology "A" level brought about a subtle shift in my thinking. For the first time I was required to design experiments, and to do this, I had to connect theoretical "book learning" with practical hands-on science. I began to really enjoy the *order* that scientific study could bring to natural things. I learned about classification, biochemistry, anatomy, genetics and so on. For "A" level, these topics were neatly broken down into simple "rules", such as "all insects have six legs", "respiration is the process of breaking down sugar using oxygen to produce energy and carbon dioxide", and "plant cells have rigid cell walls, while animals cells do not". I learned the names of the "six essential amino acids", that the structure of DNA is a double helix, and what a gene is. It amazed me that when it came to practical experiments these simple rules seemed to work. For example, in one lesson I collected gases produced by plants as they photosynthesised, and sure enough – they produced oxygen as the rules predicted; in another I dissected an ox-heart, and indeed it contained valves, just as we'd been taught, and on the day that I looked under a microscope at an onion cell, I saw its rigid cell wall, looking just like the photo in my text book. It all seemed so simple and logical, I loved it, and I wanted to know more.

So, to me, choosing to study biology at university was the obvious next step. I gained a place at Bath University, and in September 1996 I enrolled on a course in Biological Science there. Initially, degree-level biology was everything I'd hoped it would be. I learned more about the insides of cells and how they worked, about animal anatomy and physiology, genetics, plant physiology and disease resistance, and ecology and population biology, and much more. Although it was mentally challenging (especially the biochemistry and cell biology, which I've never taken to very intuitively), I found it hugely exciting. The laboratory practical sessions were quite different from those at "A" level. We were amongst the first students to use the newly built biology labs at Bath, which were pristine and very modern compared with the labs I'd used before. It did take me a while to get used to the rigorous method and routine required in the more detailed practical sessions for degree level, and for a while it seemed to me that practicals were all about following instructions, sterilising things and wearing white coats. As a result, I often found it difficult to associate the lab work with the "natural biology" that I'd seen in the outside world. Nevertheless, once I'd got beyond the basics, I found much of the practical work incredibly interesting. Plant cell culture, for example, was fascinating. I found it amazing that I could cut a tiny square from a plant leaf, put it on agar jelly in a dish and treat it with the appropriate chemicals, and by the next week's session it was covered with tiny clones of the parent plant, which could be picked off and planted out like any seedling. This felt like very high tech science, and I felt privileged to be learning how to do it.

One topic that I really took to was ecology. Here, unlike in many other areas of biological science, I could see real direct connections between what we learned in lectures, and the natural world with which I was familiar. Rather than focussing on what happens when "chemical X attaches to a cell membrane", the ecology lectures were about such things as the species richness of an oak woodland, or why a male pheasant is brightly coloured while the female is brown. Ecology practicals were a joy, on a number of occasions I remember the whole class tramping off into a nearby woodland or field, to count ants' nests, or see fungi in their natural environment, which seemed like much more "applied" biology than the lab work.

Fairly early in my undergraduate studies however, I began to get my first major misgivings about the scientific logic that had appealed so much to me during my pre-university studies. As a biology student, I struggled to accept the reasoning behind "reductionist" methodology that sought to reduce the complexity of ecological systems by isolating parts of them, or delineating artificial boundaries within them. Reductionism, I learned, is the predominant approach in conventional biological science and refers to any approach where to understand a system, it is broken down into smaller more manageable parts; these parts may then be studied in a controlled environment where external influences are kept to a minimum. The reductionist view asserts that having learned about the parts of a system in this fashion, it is possible to put everything that has been learned about it back together in order to understand the whole.

To me, a reductionist approach always seemed to leave something missing. The problem is that many biological systems cease to function when they are taken apart, and although we may learn about their component parts when they are isolated from one another and from their environments, putting the knowledge we have gained in this way back together does not necessarily provide a realistic understanding of the whole system. Knowing everything about the individual parts of a frog, for example, does not mean that we know everything about a living frog. Sadly, however, many biological researchers assure us that we *should* learn all about natural systems in this way. Actually, some go further than this, asserting that not only is it possible to learn about a living frog from its component pieces, but that if the answers are not clear from the disassembled parts, they need to be broken down even further, to molecular and biochemical levels.

I am not suggesting that biologists using a reductionist approach have forgotten that they are dealing with parts of a larger system. Rather, my chief argument against this approach is that it makes it all too easy to entirely *decontextualise* the part of the system one is studying, which might have a considerable effect on how it behaves. This could, I believe, create difficulties when it comes to relating the findings made about decontextualised parts to how they behave as part of a system in a natural context.

In my view, the limitations of a reductionist approach are most starkly highlighted in the field of ecology. In natural ecosystems the living world can seem breathtakingly complex. A single oak tree, for example, may host hundreds of species of insects, birds, mammals and invertebrates, all living in interrelated co-dependency (as prey, competitors, parasites, symbionts and so on). Throughout my biological studies, it seemed anathema to me to try to break such a system down into isolated parts, or to delineate artificial boundaries within it to understand it, as by breaking it down one would lose the interrelatedness that seemed, to me, to be so vital in the system. I felt that reductionist ecological tools, many of which seek to simplify a system so that its study is more manageable, seemed to fit natural ecosystems very poorly; indeed in many situations they need to be considerably adapted to be of any use at all.

For example, in field ecology, “quadrats” are often used to define and isolate blocks of habitat to study. In practice, using a quadrat usually involves physically demarcating one or more small squares. Having done this, it is then possible to count, measure and observe anything within the square as if it were an independently existing environment. According to the methodology, provided the quadrat was randomly and independently placed, one can deduce that any pattern in the results obtained in this way is representative of an overall pattern for the whole environment.

Superficially, a quadrat square makes things simple. It separates an area for study that is small and easier to manage than the whole location. If more than one is used, we can make comparisons within a location, such as "what are the differences between *here* and *over there*?". Tools such as quadrats allow us to reduce the complexity of a natural environment to fit a scientific paradigm.

I have had to use quadrats often enough, but each time I used them, I felt that they simplified things too much. A number of other ecological tools gave me similar misgivings. Yes, I managed to reduce the complexity of the system so I got results, but often I felt that the "essence" of the natural system was being missed in this methodology. I was left with a sneaking suspicion that by eliminating the complexity, I might have been throwing the baby out with the bath water!

Reductionist approaches are, however, very popular in conventional research practice. This is so not only in biology, but also in all other areas of science, and indeed in the social and cultural sciences, and beyond. It is easy to see why. By creating clearly demarcated boundaries within a system that allow us to quantify and simplify otherwise complex systems, we can gain a level of certainty, security and apparent predictability, and, perhaps the ultimate goal of any reductionist investigation, the knowledge of how to *control* a system.

The reductionist approach is actually a reflection of a deeper commitment in much of the Western world to *classical* philosophy and analysis. Aspects of Western thought are pivoted around classical analytical tools of enquiry and thought that exhort us to use logic and rationality to understand the world around us. Over centuries, the classical worldview, which is rooted in the philosophies of the Ancient Greeks, and was developed during the scientific and industrial revolutions, became dominant in the Western world, to the practical exclusion of all other views. I shall discuss the influence and implications of this classical worldview on modern-day science in greater detail in Chapter 2 of this thesis.

My doubts about the strong "neo-Darwinian" view, which is promoted by authors such as Richard Dawkins (Dawkins, 1976; 1986) presented another major issue that had a significant influence on the development of my thinking about biology. Dawkins advocates a view of evolution where every aspect of all natural life is considered to be the result of the activity of "selfish genes", whose only goals are to survive and to replicate. During my undergraduate studies it seemed to me that the neo-Darwinian view of evolution is very widely applied in conventional biological science, to all manner of natural systems. I, however, had major problems with accepting this point of view, which, to me, seemed to rationalise all that is *vital* in living systems in terms that are excessively minimal. As an undergraduate, I had particular issues with how the model was often applied to the social behaviour of animals, where behaviours such as altruism, cooperation, herd dynamics, mate choice and life-long partnerships were all explained purely in terms of "selfish gene" behaviour.

I also strongly disagreed with the way that a rigid neo-Darwinian view is applied by many biologists to explain all kinds of *ecological* systems and patterns, from population biology to the distribution of plants in a natural environment. I felt that what I referred to as the "Dawkins" view was applied in a very rigid and inflexible manner by some ecologists, to explain patterns in nature that might actually have far more complex origins. I felt that there were particular problems when the neo-Darwinian view was applied to ecological systems using reductionist methodologies (of the sort I have described above), as when neo-Darwinism is combined with a reductionist approach it has the capacity to exclude *contexts* in a highly compelling, yet (in my view) dangerously simplistic manner. This seemed to me to be a rigidly positivist approach that failed to appreciate that physical and behavioural patterns in natural systems are often the outcome of highly complex and irreducible factors; yet it is an approach that is very common in current-day ecological research.

As an undergraduate, while I could appreciate that the Darwinian model of evolution had its place, I found it very hard to accept that the rules of natural selection or of selfish gene behaviour were as pervasive or as fixed in the natural world as they were often portrayed to be. Appealing as it might be to assume that nature works on a small number of very simple rules, I remained unconvinced that this was so. It seemed, however, that I was amongst a minority of biologists who thought this way, and often my arguments against the strong Darwinian theme were taken instead to be an indication that I had misunderstood what I was being taught.

One or two of my undergraduate lecturers did however recognise my point of view. One of them, Alan Rayner, was later to become one of my PhD supervisors. Alan's own view of natural systems is quite different from the predominant neo-Darwinian approach in biology, and this came through very clearly in his lecture courses on fungal ecology, which I found thoroughly inspiring. Through these courses I learned to see ecosystems as *dynamic systems* of relationships. I learned that it is possible to conduct valid science without having to treat species and individual organisms simply as abstract entities in an equation, or as merely the ecological embodiment of purely selfish genes. Rather we were encouraged to think about the organisms from *their* point of view: What might they be facing in their environment that made them grow a particular way? What might an organism need to do to retain its own identity, rather than get taken over or consumed by another? And significantly, how might human presence in an ecosystem affect the relationships within?

For my final year's dissertation, I chose a project on the ecology of mosses. I had a somewhat ulterior motive for choosing this, as it meant I could spend my practical study periods in the beautiful woodlands belonging to the farm where I had lodgings. But it also meant that I could truly *immerse* myself in an ecological study. I spent many happy hours identifying and measuring the distribution of the mosses I was studying, and in trying to work out *why* they grew in the patterns that they did. I discovered that the ecology of the mosses growing on scattered logs in the woodland was quite similar to the ecology of many island-dwelling species of plant, and therefore was able to draw parallels between bryophyte (moss) ecology and an ecological domain known as "island biogeography". Having identified this connection, I then spent many hours in frustration while I tried to manipulate mathematical representations of the mosses to statistically validate what I'd seen. The project taught me several salient lessons, one of which was that getting empirical (and numerical) data to demonstrate what one has observed or experienced can be very difficult, but also that if it is ultimately achieved it can be very satisfying. Eventually I did manage to show with my statistics that the mosses were living on "islands", although admittedly, not as conclusively as I would have liked. This outcome, along with other successful biological investigations that I had conducted, has led me to prefer a quantitative approach, despite the challenges encountered when one tries to implement it in a "real life" environment. Aspects of this might be recognised later in this thesis, in my empirical study of a human organizational network.

1.3 Starting postgraduate research – beginning an association with psychology

After graduating, I felt that I definitely wasn't finished with biology yet. There was still much that I wanted to know about, and I was also fired up with enthusiasm to explore the notion of systems of relationships, which I had encountered in my studies of ecology. I was particularly enthused with a seedling idea that I'd had about connecting themes I had encountered in ecology with problems in human systems, especially in human business organizations.

I approached my erstwhile lecturer, Alan Rayner, with a view to doing some further work with him. I put forward the tentative ideas that I'd had about drawing parallels between ecological systems and human business organizations. Alan immediately took to the idea, and suggested that I consider pursuing the research formally as a doctoral study. But, having encountered resistance within his own department to his unconventional approach to biological science, he warned me that I was unlikely to gain support for my idea from the biology department. Financial support didn't concern me greatly, as I intended to finance my research by working part time, but academic support was clearly going to be necessary, and if I were going to start a PhD study it would have to be registered somewhere other than in biology. Alan suggested that my idea of transferring concepts from biology to human systems was one that might appeal to a colleague of his in the Psychology department. It was from this start point therefore, that I met Helen Haste who was at that time head of the psychology department at Bath. One of Helen's research interests was "metaphor", and at our very first meeting she explained to me that the research topic I was considering was an obvious example of a metaphor. I'd not seen it in that way before, but the idea intrigued me. Prior to that point, I had never had any contact with psychology and I had very little knowledge of what the subject entailed, and I was somewhat wary of starting work in a domain about which I knew so little.

Nevertheless, I was very keen to work with Alan, and to pursue my research questions in the way that I wanted to, and both Helen and Alan seemed to be offering me opportunities that I wouldn't find elsewhere. So I registered my research topic as a doctoral study in the department of psychology, with Helen Haste and Alan Rayner as co-supervisors.

I started my postdoctoral studies with a series of short lecture courses, seminars and associated reading which rapidly acquainted me with the areas of psychology and social science that were relevant to my research. These included theories of human communication, systems theory and dialogue, public understanding of science, technology-mediated communication, and others. Under Helen Haste's guidance (whose own speciality was critical psychology), my studies emphasised critical approaches to psychology and communication theory, and highlighted the work of other researchers who had challenged positivistic thinking as I wished to do.

These formal courses and the reading associated with them had a considerable influence on my thinking. The majority of the material was very new to me, and at times I found the unfamiliarity of it all somewhat unsettling. On the whole, however, I found these different ways of thinking about the world, and the cultures within it to be intriguing. One seminar course in particular, on the "public understanding of science" (PUS) gave me a great deal to think about. Before the seminars, I had not really considered science from an "outsiders" point of view, as I had primarily been concerned with presenting scientific findings to other scientists. The PUS seminars however caused me to consider how science might be perceived by and presented to non-scientists, including how it is portrayed in the media and in fiction. I learned how science might be used as a tool to support or refute an ethical argument, to advertise a product, glamorise a story or to give weight to a political point of view, to name but a few examples. I began to think about the cultural impact of communicating science, which was not something I'd really considered before. One topic that had a surprisingly strong influence on my thinking was the portrayal of science and technology in science fiction. Prior to this I had never really been interested in science fiction films or stories, yet after a number of seminars on the topic I was hooked. I learned to look for subtexts within the stories that alluded to cultural or philosophical issues, and in particular I learned how scientific devices and concepts might be used as *metaphors* to communicate ideas without making them explicit in the story. I watched films such as *The Matrix* many times, finding new examples of metaphor and allusion with every viewing. I began to view science fiction films and texts with a new regard for the depth that might be hidden within them. In overall terms, science fiction itself has little direct relevance to the thesis I have finally developed, but I feel my study of the topic is worth mentioning because of the significant impact it has had on my thinking.

There were some areas in the psychology seminars and readings that I studied that seemed to connect with things I already knew from biology. For example, I had already encountered systems theory (Bertalanffy, 1968), and I had touched on complexity theory in my studies of ecology, having read a little of the work by Stuart Kauffman and others (Kauffman, 1995). In some of the seminars and lectures I attended, Dawkins was also mentioned, but he was by no means presented as the exclusive voice from biology, which surprised me, given the dominance of his model that I had encountered in biological science. For example, Capra's work on holistic approaches to science was mentioned from time to time (Capra, 1996, 1982) (I had already read some of Capra's work as an undergraduate), as was Goodwin, whose view on evolutionary processes is framed in terms of complexity theory (Goodwin, 1997), and Lovelock's holistic Gaia Theory was often cited (Lovelock, 1979). These are all authors whose work I shall return to and discuss later in this thesis.

Another area in which I encountered new ideas that significantly affected my thought development was communication theory. I took a short seminar course titled "communication, interaction and task", which introduced me to some key thinkers in communication theory. It was in these seminars that I first encountered the work of Shannon and Weaver, whose transmitter-receiver model of communication (Shannon and Weaver, 1949), one of the earliest formal models of communicative processes, was to be influential when I developed my own model of communicative flow (with which it contrasts strongly). I also first heard of Grice, who in the 1970s had developed a model of communication that saw conversational meaning as something generated between speakers and hearers through dialogue, and was based on four "conversational maxims" (Grice, 1975, cited in Taylor and Cameron, 1987). In these seminars we also dealt with research that was much more contemporary, concerning technology-mediated communication. Through this I learned how different technologies can influence communication between a conversation's participants, through factors such as delays and overlap in the dialogue, lack of visual images and so on. It was becoming evident to me that meaning-generation in human dialogue can be seen to be the result of a great many dynamic factors, concerning contexts as well as the participants. I began to perceive similarities between attempts to model the emergence of meaning in conversation, and attempts to make sense of communication in biological ecosystems, both of which were dealing with highly complex situations.

1.4 Metaphor Theory

Metaphor proved to be a particularly important topic in my studies. I first looked at metaphor theory merely for interest, because in trying to find parallels between biological and human systems I recognised that I was working with a metaphor, and I thought I ought to know more about the topic. I started by looking at examples of biological metaphors themselves, for example Punctuated Equilibrium Theory (from ecology) as a metaphor for business development (Price and Evans, 1993). Soon, however, I moved on to look at metaphor theory itself, and was surprised to find that not only was it very interesting, but that its relevance to my study was far more profound and far-reaching than I had originally thought.

I found Lakoff and Johnson's cognitive model of metaphor (Lakoff and Johnson 1980) particularly thought provoking. Many of us were taught at school that metaphor is a way of *saying* one thing, but *meaning* another; it was treated as a way of beautifying language so that the reader or hearer might think more deeply about a text. Lakoff and Johnson however, developed a quite different model, which treated metaphor as a mental or *cognitive* process. As a consequence, contemporary metaphor researchers no longer view metaphor merely as a linguistic device; rather, it is considered to be a reflection of the way that we *think* about the world (Ortony, 1998). Many modern researchers suggest that the term "metaphor" refers to any occasion when we think of one thing *in terms of* another. So when, for example, we work on our computer "desktop", we are in fact using a metaphor. Moreover, if we investigate the computer desktop metaphor further, we find that it is associated with a whole collection of names and concepts that fit in with the idea of a computer being like an office desk; we use "files" and "folders", which we may discard in a "recycle bin"; we have an "Inbox" into which new emails arrive, and when we send "mail" to our colleagues, we first put it in the "Outbox". So, by using the metaphor of a computer as a desktop, a whole collection of desktop-related names and concepts are available for use as sub-metaphors. The desktop metaphor is therefore an example of a metaphorical *schema*, where metaphorical references become organised under an overall theme (Allbritton,1995). As I shall show later in this thesis, metaphorical schemas may be very powerful indeed, as they have the capacity not only to alter our language, but also to shape how and what we *think* about a topic.

My encounter with this view of metaphor had a considerable impact on the development of my thesis. I began to shift my view of using biological metaphors simply as a means of connecting two topic domains (biology/business systems), and to consider metaphor itself as a possible underlying explanation for the parallels that I had already seen. Perhaps metaphors between biological and human systems were possible because of the way in which we construct theories and concepts in both domains? I had much to work on here, but ultimately it was metaphor theory that enabled me to see the connections between the otherwise apparently disparate parts of my study.

1.5 My involvement with and contribution to Inclusionality theory.

Throughout my doctoral studies, I have continued to work closely with Alan Rayner. Around the time that I started my study in 1999, Alan was publishing early work on an approach that he (with others) was developing; he called this approach "Inclusionality". Inclusionality was developed primarily in reaction to the highly objective and rationalistic perspective that is predominant in modern science. As I have already mentioned, much of modern science is centred on a *reductionist* perspective, which seeks to break systems down into parts that may be studied in isolation from one another. The idea is that the knowledge that is gained about these reduced parts may be added together to produce an understanding of the whole system. As I shall explain in some depth later in this thesis, the reductionist approach necessitates the identification of discrete and finite *boundaries* of these parts within a system, so that the different parts may be identified and separated from one another.

By contrast, in an Inclusional approach, boundaries are not treated as discrete outlines that separate one part of a system from another; rather they are considered to be areas that identify a shift between so-called inner and outer *contexts*. In Inclusionality, it is recognised that boundaries play a key role in *mediating* the relationships between inner and outer contexts, and an appreciation of this is considered to be fundamental to our understanding of system dynamics.

Core to Inclusionality is the concept that *space* is a fluid medium that permeates, connects, relates and communicates. In other models, space is often disregarded, eliminated, or seen merely as something that separates objects from their environments. In Inclusional thinking, however, space is highly significant as the omnipresent medium that implicitly *connects* us with our environments, and with other beings within these environments.

One of the key things about Inclusionality theory is that it does not entirely reject scientific methodologies and approaches, rather it seeks to question the *assumptions* behind these approaches. In this sense it does perhaps have similarities with critical analysis in psychology, and elsewhere. Inclusionality is a view with which I have much affinity, and to an extent, this has coloured and directed the way I have conducted my research. Consequently I shall discuss Inclusionality in considerable detail later in this thesis, including how it contrasts with conventional approaches.

My own research has contributed to the development of Inclusionality theory, as well as helping to communicate an Inclusional perspective to a wider academic community. From the outset of my research, I was keen to introduce Inclusionality to academics outside of the domain of biology (Alan had already published on Inclusionality within biology). I was also keen to explore and write about Inclusional ideas of *communication* and of systems *relationships*, which in practice took me through a variety of subject domains, including (but not restricted to) both biology and psychology.

1.6 The Teamwork study

From the outset of my study I was keen to conduct some empirical research in a non-academic environment. Since I initially intended to make connections between biological science and human business systems, I kept my eyes open for an opportunity to conduct a research project in a human business environment.

The opportunity to do this actually arose fairly early in my doctoral study, when I became involved (though my non-academic work) in a construction-industry project called "Teamwork", in 2001. My association with the Teamwork project came about through my ongoing work for ATA, my father's IT systems company, where I was working part time. ATA's principal client at the time was Bourne Steel, a constructional steelwork fabrication company employing nearly 200 people. ATA designed, implemented and supported all of Bourne Steel's IT facillities. ATA and Bourne Steel were jointly involved in Teamwork, and both supported my proposal to use the event as a research opportunity.

Teamwork was a DTI funded team-working project, which was organized by a group of companies associated with the British construction industry. The aim of the Teamwork project was to bring together various companies involved in large-scale building design and fabrication, to work together collaboratively on a single "virtual" project. Teamwork was intended to focus on using collaborative work methods to tackle problems in the design and supply chain, and to improve integration and cooperation between the various parties involved in the design process.

I recognised that this event might provide me with an opportunity to study communication between people at work in a commercial environment. Also because the event was novel and "experimental", and the participants were relatively free to conduct their projects as they wished, I suspected I would have the opportunity to see how the participants organised themselves to get their projects done.

Since my Teamwork study occurred at a relatively early stage in my research, I set out with some fairly loose ideas of what I wanted to find out. My research questions were centred around looking for patterns of interaction between the participants, and of communicative flow (such as one might find in a biological ecosystem), as well as on how the participants dealt with conflict, and the effect that communicative tools such as computers affected how they conducted themselves and worked with one another. In practice I approached the Teamwork event much in the way that I would have conducted an ecological study – through observation of behaviour, collection of some specific data, and looking to interpret the data through analysis after the event.

My actual research at Teamwork took the form of an observational study on the development of communication patterns within the Teamwork environment, with particular focus on their week-long "Liveweek" event held in June 2001. Liveweek was intended to serve as an experimental "trial run" of some of the collaborative working practices. I investigated the development of interaction networks between people at Liveweek, the communicative behaviour of the teams, and their use of supportive "artefacts", which included computer models, paper-based design sketches, and other documentation.

Although this empirical research appears towards the end of my thesis, this actually does not reflect the chronological sequence of events in my research process. The "Liveweek" event took place in 2001, but the bulk of the *theoretical* work (philosophy development) took place after this. The Liveweek data, and research experience, acted as catalysts for my subsequent theory development, and it was through consideration of the Liveweek data that I developed the flow-form network model of communication that was the major theoretical outcome of my research. The Liveweek project therefore serves in this thesis as a set of findings which can be used to *exemplify* the power of the flow-form network metaphor that I subsequently developed.

1.7 The Teamwork study as a catalyst for further research on communicative networks

It was my examination of the Teamwork data that set me on the trail of network analysis. I had returned from the Liveweek event with a series of video recordings of conversations, along with a collection of basic observations that showed which participants had interacted with one another and when. I had an idea that I wanted to create a diagrammatic representation of these interactions, so I set about looking for the tools to do so. It was this research that led me ultimately to Social Network Analysis, and the associated computer tools for data analysis.

Catalysed by the Teamwork research, therefore, I began to investigate how others had studied communicative networks, and I found that there is a comprehensive literature on the subject. I looked in particular at social network analysis (Scott, 2003; Borgatti, Everett and Freeman, 2002), and also at "small world" network theories (Barabasi, 2003; Buchanan 2003; Watts, 2004), which are becoming increasingly popular in the contemporary study of networks. In Chapter 5 of this thesis I present a detailed discussion of these theories.

I soon discovered however, that I wasn't particularly comfortable with the "small world" network model, or with other similar models of communication networks. Many of these models seemed to be focussed on what happens when one joins otherwise unconnected "nodes" to form a network. But to me they didn't seem to realistically represent the flows of communication within a network, nor to effectively represent the network's contexts and environments. In my studies of biology, I had encountered natural communicative networks, such as those of fungal "root" systems (known as mycelial networks), which were quite different from these node-based networks, and which seemed to me to *embody* communicative processes far more effectively. I set about trying to work out what were the key differences between "small world" networks and natural communicative networks such as those of the fungi, and the implications of those differences. It was during one of my discussions on this subject with Alan Rayner that the concept of "flow-form networks" first emerged.

1.8 Flow-form: an Inclusional interpretation of communicative networks

The "flow form" model of network communication that I have developed, and presented in this thesis (Chapter 6 onwards) has made a significant contribution to Inclusionality Theory. As I mentioned above, the idea of "flow-form" communication was inspired by certain kinds of living network found in the natural world, such as blood circulatory systems, and fungal mycelial networks. These systems, which consist of interconnected networks of communicative tubules, not only serve to communicate *fluids* within a system, but also, due to the properties of their living boundaries, are highly responsive to their environmental contexts.

The flow-form model contrasts at a profound level with conventional models of communicative networks, which are often presented as systems of interconnected *nodes*, and it offers a radically different way of conceptualising how a networked structure could behave. The flow-form model therefore represents a shift away from the node-centred thinking of conventional network theory, towards an understanding of networks as representations of communicative *flow.*

1.9 Flow-form – model, metaphor or advocacy?

One further point that is worth mentioning here that there is a distinction between a *metaphor* and a *model*, and that this issue is of concern with regards to my own studies. It has been said that a metaphor is being used when one thinks of "one thing *as if it were* another" (Lakoff and Johnson, 1980). A model, however, can be grouped with charts, maps, graphs, diagrams and photographs, as a device for showing "how things are" (Black, 1977 (reprinted in Ortony, 1998).

In the latter parts of my thesis, I have presented "flow-form network" sometimes as a metaphor, and sometimes as a model. The reason for this is that, at this stage, I have chosen not to resolve whether it is either model or metaphor. Indeed, I have found it useful to explore the flow-form network concept *both* as metaphor and as model. As metaphor, flow-form networks can link biological phenomena with other domains (psychology, management, systems theory and so on), while as model, it has the potential to *explain* patterns phenomena that were previously unexplained by conventional models.

It has also been suggested that there is a third means by which the flow-form network might be presented: framed in terms of *advocacy.* This means presenting the flow-form idea not just as "if it were" (metaphor) something else, nor "as things are" (model), but as "a suggestion for practice". The advocacy approach is also represented in my thesis, particularly in the concluding chapters where I discuss possible future applications of the idea.

It might be suggested that the lack of resolution between these three approaches has led to some ambiguity in the thesis, and that it might have been clearer had I chosen just one approach (i.e. model, metaphor or advocacy). However, doing that would have precluded the possibility of exploring the other ideas as freely as I wanted to, and the route that I have taken has, I feel, resulted in a thesis that is a more honest representation of my own intellectual journey.

1.10 Navigating thls thesis

To help the reader of this thesis, I have presented a brief description of each chapter topic below.

Chapter 2: From Mechanism to Inclusion – a discussion of selected literature on the philosophy of science and systems

This is a partial account of the history and development of scientific enquiry in the Western world, highlighting in particular the ideas and concepts that have influenced my own research paths. It includes a discussion of the rationalistic Cartesian/Newtonian model, followed by a review of non-linear approaches that include Systems theory, Chaos theory and complexity theory, holism, and finally I discuss a recently developed approach known as Inclusionality.

Chapter 3 – Communication theory

A survey of literature concerning theories of communication. In this chapter I explain how communication theory has paralleled the development of Western philosophies, and discuss some of the contrasting models that have been developed to understand communicative systems.

Chapter 4 – Metaphor

A survey of the literature on metaphor. In this chapter I introduce the notion of metaphor as more than merely a linguistic device, and the modern idea of metaphor as a *cognitive* phenomenon. I also discuss the idea of a metaphorical *schema* as the means by which we can understand and work within a system, and finally consider how some of the existing metaphorical schemas have affected how we understand human organizations.

Chapter 5 – Conventional network theory

In this chapter I introduce the literature on network theory. I cover the development of conventional models of networks, including "small-worlds" models, and other node-based structures. The chapter concludes with a critique of modern network theory that explains how these node-based models can influence and limit our understanding of systems.

Chapter 6 – Natural networks: towards a new metaphor of networks formed through *flow*

Presents literature on naturally existing networks, demonstrating how they are manifestations of *flow-form*, rather than of interactions between *nodes* in a networked structure. In this chapter I introduce my own novel model of networks, which is based on these natural *flow-form* structures, and suggest how it may be applied as a *mental model*.

Chapter 7 – The study of flow-form networks: an introduction to the methodological issues and challenges

In this chapter I discuss some of the methodological issues and challenges associated with applying the *flow-form* network model.

Chapter 8 – Teamwork study: aims, context and rationale

This is the first in a series of four chapters that deal with my practical research in a business context. The study concerns a construction industry event titled "Teamwork". In this chapter I introduce the aims and rationale of this study.

Chapter 9 – Teamwork study: procedures

This chapter deals with the procedures I employed to collect and analyse data at Teamwork

Chapter 10 – Teamwork study: results and analysis

This chapter presents the empirical results of the Teamwork study

Chapter 11 – Teamwork study: discussion

In this chapter I discuss the results and other aspects of the Teamwork study, in relation to my flow-form network model.

Chapter 12 – Concluding discussion

This chapter includes a discussion of the challenges of transdisciplinary research, the manner in which conventional analytical methodologies can affect data collection and analysis from flow-form networks, the potential use of the flow-form network model as a model for human organizations, and possibilities for further research and development of the model. I discuss in particular the implications and potential applications of this research in the domain of psychology.

Chapter 2 – From Mechanism to Inclusion: a discussion of selected literature on the philosophy of science and systems

2.1 Introduction

We all have a history of learning and experiences that affects the way we interpret the world. In research it is important to acknowledge this; it helps others to follow our reasoning if we explain how we got to where we are today. In this and the following three chapters I shall introduce the prior research and philosophies that have influenced my own ideas, so that the reader can recognise their precedents and follow my reasoning in the subsequent theoretical chapters of this thesis. In this chapter I shall discuss how we might have arrived at our contemporary views of the world, beginning with the development of classical orthodox models of thought, which are prevalent in modern scientific investigation. I shall then move on to discussing a number of other models that contrast with the classical worldview, including non-linear and "systems" approaches, holism, and a newly emerging viewpoint known as Inclusionality.

2.2 Classical modes of enquiry

The classical approach to enquiring about the world has long been dominant in Western society. This view originated in Ancient Greece, most notably in the writings of Aristotle. Aristotle believed that knowledge of the natural world should be based on what is *perceived* to exist there. He maintained that one could use the concrete and material evidence gathered by our *senses* as a start point, from which one could build an understanding of the world that is based on reasoning and logic. In subsequent years, Aristotle's rationale-based approach was discarded in favour of the church-led dogma that dominated the natural sciences during the Middle Ages. Centuries later however, the philosophers who were instrumental in the Scientific Revolution of the 16th and 17th Centuries returned to Aristotle's line of thought, and his evidence-based rationale became highly influential in their own philosophies. In fact it remains so in modern times, and even today we still sometimes refer to "Aristotelian logic", as it has played a fundamental role in how many think about the world.

The Scientific Revolution, which took place during the sixteenth and seventeenth centuries, was brought about by a succession of philosophers including Copernicus, Galileo, Bacon, Descartes and Newton. These giants of the philosophical world all contributed towards a line of thought that was to become the *mechanistic* worldview. This contrasted strongly with the prevailing view that had developed during the centuries that spanned the period between the Greek philosophers and the Scientific Revolution. During those "dark ages", the Christian church dominated philosophical thought, and consequently, until the Scientific Revolution began in the sixteenth century, with the works of Copernicus, it was widely believed that the cosmos, and everything within it was created, maintained by, watched over and judged by an external Creator. Theology, philosophy and science were, at that stage, inextricably linked. Fundamental in this view was a geocentric model of the cosmos, where the Earth lay at the centre of the universe (placed there by God), orbited by all the other heavenly bodies (planets, stars and so on).

Copernicus however, was the first to suggest that the earth lay not at the centre of the universe, but that it was but one part of a system of planets that orbited the sun. At first this model was, predictably, shunned by the Christian church, which considered it to be heretical. Slowly however, as a result of work by philosophers such as Kepler and Galileo, and later Descartes and Newton, the model began to gain acceptance.

What was most significant about this newly emerging view of the cosmos was that it no longer demanded that God the creator be situated at the centre of the universe, controlling and causing action in all other areas. Rather, in the new scientific view, God was believed to be the creator of a *machine-like* system of parts that function together as a complex whole. God created the system and the laws by which it functioned, but his action was not necessarily required to explain the action of the system. Like a clockwork mechanism, once started, the cosmic machine would run of its own accord.

The French philosopher, Rene Descartes was a key instigator of this mechanistic view (Sagan, *et al* ,1997; Tarnas, 1991). Descartes began from the initial assumption that the only thing of which he could be certain was the existence of his own doubting mind. With this as a "first principle", (the only one of which he could be certain to be true), he used a process of logic and reasoning to develop further philosophies about the nature of being. Principally, he developed a theory whereby all things in the world exist as either "*res cogitans*" (thought, spirit, experience and the like) or as "*res existans*" (material substance, matter, the physical world etc.). Descartes proposed that the only beings in the universe that embody "*res cogitans*" are God, and human beings (because we have consciousness). Descartes' logic led him to assert therefore that all things that are neither God or human, are machine-like automata that function according to a set of pre-determined rules. Descartes believed that it was possible to deconstruct the "machine" and gain an understanding of the whole by examining the component parts.

It was, however, Isaac Newton who managed to distil and unite the newly emerging mechanistic worldviews of these various philosophers into a physical model that would transform Western science (Tarnas, 1991). Newton developed three fundamental physical laws (inertia, force and equal reaction), along with his theory of universal gravitation, which explained and exposed the mechanisms by which a heliocentric (sun centred) cosmic model would work, as well as a great many other natural phenomena.

So, as a result of the work of these various pioneering philosophers, the Scientific Revolution took place, and the mechanistic worldview was born. The birth of this view was to be a pivotal point in the development of Western science. The Cartesian/Newtonian view of the world as a giant machine has permeated through history to become fundamental to the way that most scientific research is carried out today. Today, most scientists implement a mechanistic view in the form of a methodology, where systems of any sort are considered to be constructed from "parts". In this methodology, physical and living systems alike are disassembled, to their "component parts", before being described and investigated. The knowledge gained in this piecemeal manner is then reassembled, to build a picture of the whole system. This approach is known as *reductionism.* The reductionist approach, whereby systems are deconstructed to smaller and smaller components in order to gain an understanding of the whole system, has become deeply embedded in the way analytical research is conducted today.

One area where one might suppose the mechanistic view not to have become so dominant is in the life sciences, where because one is dealing with living organic systems, it might be thought that some other paradigm, such an organic model, as opposed to a mechanistic one, would be favoured. But paradoxically, the conventional approach to biological science is often *highly* reductionist. This stems again from the powerful influence of Descartes and Newton, who sought to explain nature in terms of mechanism. In biological laboratory science the approach is often highly reductionist. For biological lab work, the conventional approach is to extract an organism, let us suppose it's a plant, from its natural living environment, and place in a sterile and "controlled" laboratory, where all aspects other than those that are being examined are controlled or accounted for. Ostensibly this is done to simplify the investigation, so that only one part of the complex ecosystem that the plant normally inhabits need be examined, i.e. the plant itself. Often the focus of interest is at a level lower than the whole organism. So, to further study the functioning of the plant, it is broken down, to leaves, flowers, roots etc. and each part investigated separately. Scientists have even developed techniques that allow them to culture parts of an organism after they have been removed from the system, as in plant cell culture, where parts of a plant can be kept alive in a Petri dish, through the addition of nutrients, hormones etc., and the exclusion of microbes such as bacteria, that would otherwise cause the cells to decay. The principle is that many different researchers may work on different aspects of plant structure and function, and that the findings they all individually make can be pieced back together to create an understanding of the plant as a whole.

The connection of the parts that have been studied using a reductionist approach usually involves a search for sequences and cause-and-effect relationships. A system that has been analysed reductively is often characterised by the exposition of linear relationships between elements, and by hierarchies. Hierarchies within a system are significant, as they engender a structure where some elements of the system take precedence over others. Hierarchies, whether real or imposed, suggest that parts of a system are more *powerful* than others.

A key goal of reductionism and classical analysis is to produce an understanding of systems that permits their behaviour to be *predicted*. Once behaviour of a system can be predicted, and cause-and-effect relationships within it are understood, one has the potential to exert control over it and to have influence over its future behaviour.

The apparent advantage of the reductionist approach is that it breaks complex problems down into manageable parts, and there is no question that Western reductionist science has told us a great deal about the world in which we live, as well as giving us many tools with which we can control it. Western science, and its reductionist methodology have given us breakthrough technologies, such as antibiotics, medicines and so on. It has at the very least given us a place from which to start our investigations, allowing us to build our knowledge of the world around us piece by piece, working from the simple to the complex.

This reductionist approach, however, make some significant assumptions. The first of these is that the world *can* be broken down into smaller manageable-sized parts, and that the things we learn about these isolated parts will actually relate to the whole systems from which they originate. The second is that it that is *possible* to make clear distinctions between the different parts of a system, and that one could take an imaginary pair of scissors and "cut out" the object of interest so that it can be separated from its environment. This view has been referred to as "discretism" (Rayner, 1998). In a discretist approach, objects and phenomena of interest are *defined* so that they may be identified independently from their surroundings.

The discretist view also has some important philosophical implications, and could be said to require a number of "leaps of faith" to be able to work in the real world. At a fundamental level, discretism assumes that any entity within a system *can* be defined independently from its context, and that it is *possible* to conceptualise any part of a system as an independent entity. This appears easy to do when dealing with say, berries on a blackberry bush – we can pick the berries and hold each one individually in our hands. But in many systems parts cannot be so readily distinguished, such as a "seat" on a long gym bench, or the branches on a tree. In these examples it is much harder to distinguish where one seat ends and the other begins, or where trunk turns into branch.

So, one of the repercussions of a discretist approach is that boundaries in the system of study are required to be precise. This can either be achieved through identifying physical structures – as in the blackberries (the berries are apparently distinct from the bush, as they can be "picked off"), or through imposition, which is what one would have to do to define a "seat" on the bench.

In a discretist paradigm it is thought to be possible to separate anything from anything else; to pick out "A" from "that which is not A". This polarised view should be familiar to those who have studied Western philosophy, as it is sometimes known as the "Law of the Excluded Middle", it reflects the Aristotle's "two value logic" and the Cartesian concept of "Dualism" (Haste, 2000). Dualism separates entities in a bipolar fashion. As I mentioned earlier, Descartes proposed that the workings of the mind could be separated from the body, effectively creating a clear distinction between that which is "thought", and that which is "substance" (Tarnas, 1991). Dualistic thinking is one of the dominant features of the classical worldview. This mode of thought encourages us to make clear distinctions between one thing and another, be it subject and object, observer and observed, content and context, self and other, male and female (Haste, 1993), and inner and outer (Rayner,1997). These bipolar distinctions have directed the paths of Western thought, promoting a focus on clear *categories* of being, and a steering away from that which is "fuzzy", without boundary, or ambiguous (Haste, 2000). As a result of dualistic thinking and approaches, which have been particularly influential in Western *science*, the predominant scientific viewpoint is one that values clear definitions, and seeks to clear up ambiguity or lack of clarity. That which is "between", a "best fit" or an "uncertainty" is less valued.

2.3 Systems theory, chaos and complexity

The Cartesian/Newtonian worldview has not gone unchallenged. At sporadic intervals since it was first developed, alternatives to the dominant mechanistic worldview have appeared. For example, during the late eighteenth and nineteenth centuries the Romantic movement, which was pioneered by authors, painters, and other artists of the day, shifted the balance of favour away from the mechanistic paradigm (Capra, 1996). During that time, the influential philosopher Immanuel Kant (1724-1804) argued that the processes of scientific enquiry can only provide insights that are mechanistic, but that organisms are not like machines, and that they exist as self-reproducing, self-organizing wholes (Capra, 1996; Kauffman, 1995). Later in the nineteenth century however, the mechanistic view regained its dominant hold, spurred on by the development of microscope technology that lead to significant advances in biological science (Capra, 1996). It was during this era that modern cell biology and microbiology were born, which of course was driven a significant step further by the work of Louis Pasteur (1822-1895), who discovered the first antibiotics.

Early in the twentieth century there was a further shift away from Classical Analysis toward what we now refer to as the "holistic" movement. The development of the quantum theory of physics during the 1920s and 30s revolutionised the world of physics and mathematics. Quantum theory represented a radical shift from classical Newtonian physics and analytical reductionism. Unlike the Newtonian view, which considers matter to be completely solid, according to quantum theory, at a subatomic level matter exists as a pattern of *probabilities* (Capra, 1996; Penrose, 1999). This revelation threw Classical Analysis, with its reliance on the Cartesian distinction between the substantial and the insubstantial, into turmoil. A bevy of physicists and mathematicians, including Planck, Bohr, Heisenberg and of course later Einstein (Penrose, 1999) published work related to quantum mechanics that remains influential today.

The physics-led advances in quantum mechanics opened a path that led researchers in other sciences toward new non-classical approaches, particularly in biology, but also in the social sciences and psychology. For example, a number of psychologists in the 1920s began to develop a view of human psychology that involved pattern-recognition, and concerned "wholes", rather than parts, resulting in a field of psychology known as Gestalt theory (Greenfield, 1995). Gestalt theory states that the way living beings perceive the world around them is not as a series of isolated elements, but as integrated patterns that give rise to meaningful wholes. The work of the Gestalt psychologists had significant influence on other researchers. It was instrumental in the development of Social Network Theory (which will be discussed in detail in Chapter 7 of this thesis), and also led directly to the rise of systems thinking, and systems theory.

2.3.1 Systems theory and cybernetics

Systems theory is a term coined by Bertalanffy in the 1940s (Bertalanffy, 1968), it deals with whole systems, rather than their disassembled parts. By contrast, the focus in systems theory is on the *interactions* within and between parts of a system, and on the interactions between a system and its environment. Context is therefore given some recognition in systems theory. Bertalanffy believed that there are general "systems" principles that apply to many different kinds of system, be they biological, physical, chemical etc. To study a system using systems theory was intended to bring these general principles to light. Some of the principles that Bertalanffy identified as "systems concepts" include the way that systems deal with inputs and outputs through processes, and how information can be viewed as a currency of communication.

One of the key points raised by Bertalanffy was the difference between *closed* and *open* systems. Closed systems are isolated from their environment; they have no inputs or output exchanges with anything outside of their boundaries. The boundaries of a closed system are completely impermeable, and as such they define the extent of the system's reach. Until the development of systems theory, most of physics dealt only with closed systems. Thermodynamics specifically states that its laws only apply to a system that is closed.

A closed system will tend to move towards greater order; to increase its *entropy* until a maximum level whereupon a state of *equilibrium* is reached. In a closed system this equilibrium state is achieved, and maintained, without the input of further energy than the system already contains. Upon reaching a state of equilibrium, however, the system is effectively "fixed" and unable to perform any "work" (Bertalanffy, 1968).

In the living world however, no system is closed; living systems have permeable boundaries, and are engaged in constant dynamic exchanges with their environments. According to Bertalanffy, living systems tend toward a "steady state", which is a state of *dynamic* equilibrium. An open system that is maintaining itself at a steady state is apparently in equilibrium, yet it is not actually in a state of true physical, chemical or energetic equilibrium. Rather, it is maintained dynamically in a non-equilibrium state, at a point that is not the level of maximum entropy were the system to be made closed. In order to maintain this state of dynamic equilibrium, an open system requires energy input. The benefit however, is that an open system is capable of performing "work" (Bertalanffy, 1968).

At around the same time that Bertalanffy was working on systems theory, a group of mathematicians, neuroscientists, social scientists and engineers began work on a novel system model that became known as *cybernetics.* The word cybernetics is derived from the Greek term *kybernetes*, which means "steersman". Cybernetics has been defined as the "science of control and communication in the animal and the machine" (Wiener, 1948). During the 1940s, this initially diffuse group of researchers organized a series of now famous meetings known as the Macy Conferences, which were held in New York City. In these meetings, this group of researchers, who included Gregory Bateson (a biologist/ecologist), Margaret Mead (a social scientist) and Norbert Wiener (a mathematician), collaboratively developed the theoretical framework of cybernetics. Central to cybernetic theory are the concepts of *feedback*, and *feedback loops.* The principle is that in any autonomous system, processes are controlled and self-regulated by causal cycles, where the outputs of processes are connected together in cycles, with the output of each process becoming the input for the next. The nature of the connection between each process determines whether it is a *positive* or *negative* feedback relationship. This is illustrated in Figure 2.1.

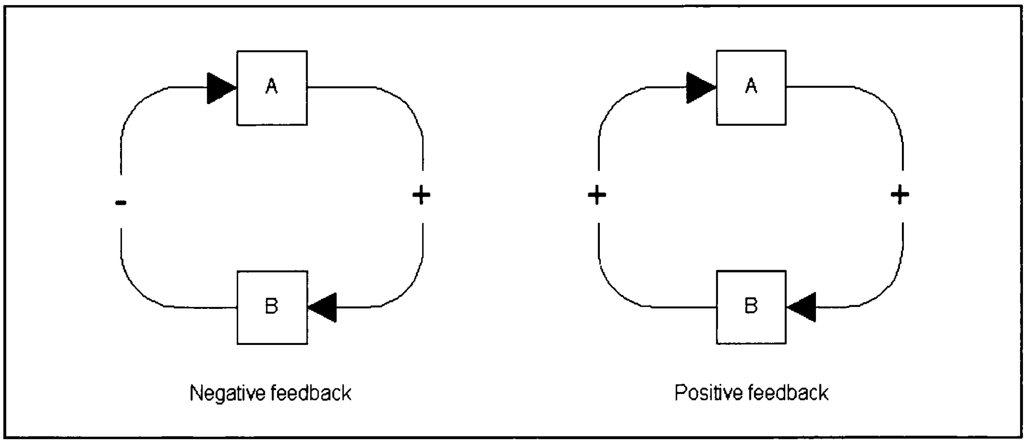

Figure 2.1. Feedback relationships. When the output of process A amplifies the reaction of process B, and the output of process B in turn amplifies the reaction of process A, then the relationship between them is known as a *positive* feedback relationship; when the output of process A augments the reaction of process B, but the output of B diminishes the reaction of process A, the relationship is known as a *negative* feedback relationship.

Closely connected to cybernetics is Shannon and Weaver's "information theory" (Shannon and Weaver, 1949). In information theory, information is viewed as a measure of uncertainty or entropy; the greater the amount of information, the lower the uncertainty. Shannon and Weaver's model deals specifically with how information is transmitted. They postulated that for information to be transmitted, it has to undergo several stages. Firstly information originating at a source is converted into a *message.* A *transmitter* then translates this message into signals that can be transmitted along lines or channels to the *receiver.* This receiver then converts the signals into a message again that is decoded and interpreted. This model of information transmission was originally targeted at engineering communication, but in subsequent years it has been applied in many different domains, from telecommunications to biology, social sciences and human dialogue.

Henri Atlan has made connections between information theory and biology, specifically in terms of the immune system (see Atlan and Cohen 1998). In animals, elements known as antigens and antibodies are key components involved in an immune response. An antigen is any molecule that triggers an immune response; an antigen might be a molecule on the outside of a pollen spore, or a cold virus for example. An anti*body* is a molecule produced by the immune system that attaches to and neutralises antigens. The relationship between antigen and antibody is highly specific, often with a single type of antibody being produced to target a specific antigen molecule. In their (1998) paper titled "Immune information, self-organization and meaning", Atlan and Cohen explain that the relationships between antigens and their associated antibodies could be viewed as a means of transmitting *information*, where the antigen is treated as a transmitter and the antibody as the receiver.

Although Atlan bases his model on Shannon and Weaver's information theory, he does make some important distinctions. Significantly, Atlan argues that the way in which extraneous information or "background noise" applies to a biological context is quite different from that of the engineering context in which Shannon and Weaver originally applied their model. In an engineering context, noise is seen as a factor that reduces the quality of the information and which should be cut out for the quality of the information to be maintained. Atlan however, argues that in a biological environment, noise is vital to the system as a means of providing *complexity* from which genetic mutations might occur, enabling the system to change and adapt. As Atlan points out, this ability for information to be adapted or to be added to is something that is not accounted for in Shannon and Weaver's original theory.

Systems theory, cybernetics and information theory therefore represented radical moves away from the classical mechanistic models of the natural world that had held sway until then. In contrast to the Cartesian/Newtonian preference for studying objects in isolation from one another, these new models considered the *processes* and *relationships* between objects in a system to be as significant, if not more so, than the objects themselves. The systems view only made sense if one looked at the system as a whole. The classical reductionist methodologies were of little use in a systems theory paradigm, and so these new models required the development of a whole new set of tools.

Some of these tools appeared in the form of the new domain of *non-linear mathematics*. Non-linear techniques provided a new way of dealing with the mathematics of complex natural systems; systems that didn't fit neatly into the classical Newtonian paradigm. Rather than normalising data so that it would fit into a traditional linear mathematical model, non-linear techniques allowed iterations and feedback loops to be accounted for. Iterative and *self-similar* [1]patterns are very commonly encountered in the natural world, so the new non-linear mathematics had direct relevance to real-life natural systems. The study of non-linear mathematics soon gave rise to two new fields of science: "chaos theory" and "complexity theory".

2.3.2 Chaos theory, complexity theory and emergence

Chaos theory came to prominence during the 1980s and deals with systems that apparently follow the normal rules and laws of physical systems, but do so in a highly unpredictable fashion (Gleick, 1987; Kauffman, 1995; Cambel, 1993). Chaotic systems can be found in many different domains; examples that have been studied include the turbulent flow of fluids, irregularities of the heartbeat, growth of certain insect populations, the dripping of a tap and the collisions of atoms in a gas (Stewart, 1990). Chaotic systems are extremely sensitive to initial conditions, and even the smallest event can trigger large consequences. A frequently quoted demonstration of this is the "butterfly effect" in weather systems, where a butterfly that flutters its wings say in Tokyo, could set off a chain of chaotic events in a weather system that result ultimately in a hurricane in Brazil a month later (Cohen and Stewart, 1995).

Kauffman explains, however, that the only reason that the behaviour of a chaotic system is unpredictable is that its extreme sensitivity to initial conditions means that one could never identify all of the factors that will play a role in its behaviour (Kauffman, 1995). To use the example I have just quoted, if one were able to precisely identify, to the minutest detail, every aspect of the butterfly's movement, then one *would* be able to predict how the chaotic system would react. The problem however, is that a chaotic system is sensitive to an *infinite* degree, and empirical science does not, nor ever will, allow us to measure in sufficient detail or with enough precision to meet this sensitivity.

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[1] Self-similar patterns are patterns that have structural similarity at different levels of magnification

Complexity theory developed from chaos theory and represents the body of research concerning systems that have *complex* characteristics. Complexity theory concerns systems that exhibit complex global behaviour as a result of the local interaction of components, or "agents", where the behaviour of the components is determined by relatively simple rules (Cohen and Stewart, 1995). Like chaotic systems however, the outcomes of these local interactions may not be linearly related to the initial conditions of the system (Miliata, 1997), and so the global action of a complex system cannot necessarily be predicted from an understanding of the behaviour of the lower-level components alone. Complex behaviour may be found in many different kinds of system, from traffic flows, to cell differentiation, to population dynamics, and turbulence. Complexity science is relatively young, and although many are studying complex systems, a definition of complexity hasn't really been settled upon yet. The consensus seems to be that the one thing that complex systems have in common is the fact that they are complex! (Cambel, 1993).

Some complex systems exhibit features that are referred to as "self organization" or "emergence". These systems, which are fundamentally chaotic, or complex, have the capacity to produce patterns that are seemingly non-chaotic and predictable in behaviour. To return to an example that I used earlier, the weather is a chaotic system with emergent properties. Although the precise initial conditions that trigger individual weather patterns cannot be identified, or used to predict the detail of an outcome, the global weather system does produce some *emergent* patterns. These patterns, which include cold and warm fronts, recognisable cloud formations and so on, can be used to predict the overall behaviour of the system (Holland, 1998). Another example of an emergent feature in an otherwise chaotic system is the Great Red Spot on the surface of the planet Jupiter (Ball, 1999; Kauffman, 1995). Jupiter's atmosphere is a chaotic system of turbulent gases, yet amongst its apparent disorder, the red spot remains constant and has done so for at least several centuries. The red spot is actually a vortex of swirling gases; basically it is a persistent storm system – it is a self-organized zone of constancy amid an otherwise chaotic system.

In the non-linear sciences, *boundaries* are treated quite differently from those in the classical Cartesian/Newtonian model. In the classical model, boundaries are often either ignored, or considered merely to be locations of entry and exit to the system. By contrast, in systems, chaos and complexity theories boundaries are viewed as *fixed* locations where important phenomena occur. It is known that emergent phenomena are more likely to occur at the boundary between a chaotic system and one that is ordered than elsewhere in the systems (Kauffman, 1995), giving rise to the term "edge of chaos", which refers to these boundaries.

Central to all of these non-linear theories (chaos, complexity, and to a certain extent to systems theory also), are the concepts of non-linearity itself, and of non-locality. Actions or events in a chaotic or complex system may have consequences that are apparently not directly connected; and local events in a system may have global consequences. This contrasts with the classical Cartesian/Newtonian model where cause and effect are always directly and closely linked. It has also meant that, at least for non-linear systems, researchers have had to review the way that they emphasized prediction and control in a system. Chaos and complexity theories suggest that it will never be possible to control some kinds of system, as their behaviour is so unpredictable that it will never be possible to be certain how they will respond.

Despite the differences between the classical analytical model and the new whole systems models of systems theory, chaos and complexity theories, they do still have elements in common with the mechanistic view. For example, the systems theory search for general systems concepts and processes clearly reflects the classical search for cause and effect relationships, and for definable stepwise processes that lead from and to particular events or phenomena in a system. In essence, in searching for "processes", the researcher is still seeking to identify linear relationships that are pre-eminent in classical approaches to systems.

Associated with this is a misunderstanding of what prediction and control imply for a chaotic or complex system. In chaos theory it is accepted that the system is highly sensitive to initial conditions, and it is for this reason that a chaotic system is unpredictable. However underlying this is an implicit assumption that if it *were* possible to account for and control all of the variables in the starting conditions then it would theoretically be possible to predict how the system would react. This assumption again harks back to the classical dependence on cause and effect relationships; only here in the case of chaos theory it is assumed that one will never be able to pinpoint the cause.

Finally, the novel theories (systems, chaos and complexity) all retain an analytical aim to *define* elements or parts of a system, or to define the system itself, with such questions as: "is it chaotic or is it complex?", "does the phenomenon occur at the boundary, or outside of it?". Indeed the desire to define the boundary itself points to the lack of separation between these new approaches and traditional analytical approaches.

Therefore, one must note that while systems, chaos and complexity theories all offer a new way of looking at systems, they do not provide a paradigm that is entirely free from the limitations of classical Cartesian/Newtonian analysis. As a result, these theories still involve to an extent putting on "positivist glasses" that restrict one's vision to that which is rational, definable and analysable.

However, the development of these "systems" views in science, mathematics and physics has had significant impact. They have brought about a subtle but significant change in the way many think about systems in conventional science, and legitimised the "whole systems" viewpoint. They have also prompted many scientists in other domains to think otherwise about their own subjects. For example in the biological sciences, where systems views are often refuted in favour of highly reductionist Darwinian approaches, "whole systems" approaches based on the complexity viewpoint are now becoming accepted. Brian Goodwin is one such proponent of the application of complexity sciences (Goodwin, 1997). Goodwin, a theoretical biologist, takes the view that the Darwinian evolutionary model *alone* cannot explain all natural phenomena, and that complexity and emergent processes are sometimes the reason that a higher level of organization arises in natural systems.

2.4 Holism

In the latter half of the twentieth century the view that we now call *Holism* was significantly expanded. System, chaos and complexity theories suggest that many natural systems cannot be entirely understood through reductive analysis alone, and that certain properties only emerge when the system functions as a whole. By contrast, holism maintains that natural systems can *only* be understood by looking at them in their entirety. In this way then, the holistic approach differs significantly from the non-linear models of chaos and complexity theories, it also presents a view that is in direct opposition to the classical Cartesian/Newtonian approach.

In recent years, holism has become explicitly connected with ecology, and particularly with what is now known as "deep ecology" (Capra, 1996). In contrast to "shallow ecology", which considers humans as separate from nature, deep ecology treats humans as part of their environment, like all other species. It sees the world not as a series of isolated objects, but as a complex network of interrelated systems.

Some proponents of the holistic view consider all natural systems (including human systems) to be organic and indeed to be organisms in their own right. The first to do this was James Lovelock, an atmospheric chemist who developed a model of the world that he called Gaia (Lovelock, 1979). Gaia theory treats earth as a living organism, with self-regulating internal processes that make it a self-sustaining system. Apart from using heat from the sun, according to Gaia theory, the earth manages itself entirely from within. Lovelock named the model Gaia after the Greek goddess of the Earth. A key aspect of Gaia theory is that it considers the earth's atmosphere to be maintained and actively regulated by the sum of all living organisms on the planet (Lovelock and Margulis, 1997). Effectively, Lovelock's model is a view that unites the earth's surface, life and atmosphere together a single *cybernetic* system (Sagan and Margulis, 1997).

Initially, many orthodox scientists rejected Gaia theory. The concept of Gaia struck at the heart of their classical modes of enquiry as it implied that the earth could not be understood merely through investigating its internal mechanisms and processes, rather, it was necessary to consider it as single unified system. One scientist who criticised Gaia theory particularly strongly in the early days was the evolutionary biologist, Richard Dawkins. Dawkins, whose book titled "The Selfish Gene" had been published in 1976, three years prior to Lovelock's "Gaia", was a fierce advocate for the powers of Darwinian natural selection. Dawkins believed that all life on Earth was the result of evolutionary selection processes, which determine that only the most successful individuals of a species survive to reproduce. According to Dawkins, Gaia theory, with its implication that the Earth was a living organism, was contrary to the laws of natural selection. For Gaia theory to work, said Dawkins, there would have had to be a number of competing Gaias, so that natural selection could determine which of them was most fit and would survive. Dawkins referred to this as a form of "interplanetary" selection, and laughed the whole of Gaia theory off as being highly improbable (Dawkins, 1982).

To counter these arguments, Lovelock developed a computer model of Gaia to convince sceptic scientists (Lovelock and Margulis, 1997); he called it "Daisyworld". Daisyworld was a "virtual" planet that was warmed by a sun. Only two species, black daisies and white daisies inhabited it. The whole of this virtual planet was moist and fertile enough to support these daisy plants, but the temperature across the planet was allowed to vary, and the plants could only grow within a certain temperature range. The daisy plants were able to regulate the temperature locally, black daisies warmed the environment (because being black they absorb heat), and the white daisies cooled it (as they reflected the sun's rays). Overall this computerised model showed that the daisies enabled the planet to self-regulate its temperature. In this very simple model, the self-regulation only worked for a limited time, and eventually the planet became too hot to sustain life. However, Lovelock later developed more complex models with greater numbers of species that were able to self-regulate the temperature for longer periods. As a result of these studies, Gaia theory began to gain recognition within the scientific community, and subsequently a number of scientific research teams worked with Gaia as their theoretical start point (Capra, 1996).

Another proponent of the deep ecological view is Ervin Laszlo (Laszlo, 1996). Laszlo's model takes an integrated view of nature, stating that natural systems connect different levels of order in the natural world. Like Lovelock, Laszlo considers natural systems to be self-organizing, and self-sustaining.

Laszlo also says that groups of objects or organisms may form "supraorganic" entities that have properties that are "more than the sum of their parts". For example, the neurons that collectively form the human brain are not independently conscious, yet when functioning together in the brain, consciousness emerges. Another of Laszlo's examples is that of a football team, independently the team members have their own identities and skills, but what makes the team "work" is their ability to co-relate during a game, coalescing to form a functional whole that we see as a "team". The supraorganic group, says Laszlo, has characters that are not just the features of the members that make it up, but also of the relations between the members.

Fritjof Capra is another influential scientist who has developed a non-mechanistic post-Cartesian worldview, basing his theory of systems on "deep ecology" (Capra, 1996). Capra, originally a theoretical physicist, believes that living systems theory must be a synthesis of three approaches:

1) A study of pattern (relationships)
2) A study of structure (physical embodiments)
3) A study of processes (activities within the system)

Capra's now famous first book, The Tao of Physics, drew parallels between modern physics and Eastern spiritual worldviews such as Buddhism and Hinduism (Capra, 1976). In doing so, he triggered the beginnings of an acceptance in the physical and mathematical sciences of a holistic perspective. Subsequently, Capra published work expressing similar theoretical shifts in the sociological sciences (Capra, 1982) and in the life sciences (Capra, 1996). Although initially regarded with suspicion by many scientists, Capra is now recognised as one of the leading advocates for the holistic worldview.

2.4.1 Problems with the holistic view

Although holism avoids the problems associated with the classical reductionist approach, it is not without its own limitations. The classical worldview seeks to understand systems by taking them apart, while the holistic view seeks to understand systems by looking at them as functional wholes. One challenge presented by this holistic approach is that *all* systems are considered as wholes, and are irreducible. This means that there is little scope for the development of methodologies that determine what lies *within* a system.

As Rayner argues (2003), holism can encourage a view where, since all things are considered to be related to one another, their boundaries are effectively assumed to be completely permeable, or indeed absent. Conceptually therefore, this absence of boundaries dissolves any distinction between inner and outer spatial contexts, all contents of the system become mixed together in a space-including, but undifferentiated "pea soup". In such a view, *context* actually becomes the sum of all *contents* and there is no enveloping "outside". Paradoxically, in such a holistic view, which is apparently deeply connected with ecology, there is no "environment", no external surrounding: the system is *completely* self-contained as a "whole".

It might be suggested that this issue arises because holism redefines what a boundary actually *is.* For example Bateson, who was an early advocate of a holistic view (his particular viewpoint was framed in cybernetic terms), questioned the idea that boundaries are defined by their physical surfaces (Bateson, 1972). According to Bateson, one could seek to understand a system in terms of information flow, rather than of relationships between physically distinct parts. This he illustrates with an example of a blind man using a cane to navigate his way down a street. According to Bateson, if one only considers the flow of information in the system, the physical distinction between the blind man and his cane becomes irrelevant. Instead, the information flow between street, cane and man become the source of *identity*, and effectively they become one continuous system. Bateson further argues that boundaries could be defined by the *behaviour* one is trying to explain. So, if one is trying to explain how the blind man walks, one needs to consider the street, the man, the cane, and so on. When the man sits down to eat his lunch however, the cane and the street become irrelevant, as they play no part in explaining how he eats.

Bateson's approach does, however, begin to distance us from the kind of holism put forward by those such as Lovelock and Capra. Other authors have tackled the issue of boundaries in holistic systems in a way that allies more closely with models such as Gaia theory. Primavesi for example, sees boundaries as regions of "structural coupling", where systems define and distinguish parts from one another, but also as the means by which they relate themselves to the whole in a process of continuous dynamic transformation (Primavesi, 2001). Similarly, Volk (1995) describes boundaries in living systems as "expressions of both separation and connection", that may exist physically (as skin, cell membranes and so on), or as functional features of an entity that relate insides to outsides (the human immune system for example).

This kind of holistic approach does, I believe share some similarities with a newly-emerging perspective, known as "Inclusionality theory", which has been developed by Rayner and others (Rayner, 1997; 2002). Inclusionality contrasts with, whilst including elements of both the classical analytical and holistic approaches, yet it overcomes many of their inherent problems by looking at systems from an entirely novel perspective. The "Inclusional" view is one with which I strongly empathise, and much of my own research has been framed terms of Inclusionality theory.

2.5 A new approach: Inclusionality

Inclusionality theory is a radical new approach that considers an understanding of the relationships between contents and contexts to be fundamental to understanding living systems. It contrasts most strongly with the Cartesian/Newtonian model, as it takes a systemic view, but also contrasts with the holistic notion of the absence of distinguishing boundaries. Inclusionality does have some aspects in common with the views of authors such as Goodwin and Capra (Goodwin, 1997; Capra, 1996; Capra, 2002) who both recognise the systemic significance of communicative dialogue and relationships between organisms and their environments, but interpret the latter in terms of "feedback", which effectively splits space and time across a divisive boundary. Unlike many conventional views, which are based on binary, or dualistic logic, the Inclusional view is based on *ternary* logic. Instead of looking to identify *either-or* relationships, an Inclusional view permits things to be *both-and*. Not black *or* white, but *both* black, *and* white; not inside *or* outside, but *both* inside, *and* outside. This novel perspective therefore represents a significant shift from conventional dualistic thinking.

Core to Inclusionality is an understanding of the significance of *space* and its inseparability both from time and matter/energy. In other models, space is often either disregarded, eliminated, or seen merely as something that separates objects from their environments: in effect an "absence" of "presence". In Inclusional thinking however, space is highly significant as an inductive "presence of absence", which permeates within, around, and through every thing, living or otherwise. It implicitly *connects* us with our environments, and with other beings within these environments. To illustrate: we might think that we are physically separated and distinct from this page that we are reading. However no matter is entirely solid, so both we and the page comprise molecules that are surrounded by and contain spaces; our skin may seem like a impenetrable barrier yet it is not, we have pores that allow gases to pass through, and the cells themselves are surrounded by "intercellular spaces". So, the space that surrounds our bodies is also connected with the space inside them, and also inside every object around us. Space connects us with everything else. It is everywhere, literally.

This shared nature of space means that we share a common medium with everything else around us. Space is this medium, in effect the ultimate *fluid* that pervades and communicates and so gives fluidity to all. When an object moves to fill a space, the space *displaces* reciprocally to accept it, and *vice versa* in a Universal application of Archimedes' Principle. But actually the space was already there from the beginning! Hence, the Inclusional relationship between space and object is a bit like Terry Pratchett's observation on the speed of light:

"Light thinks it travels faster than anything but it is wrong. No matter how fast light travels it finds the darkness has always got there first, and is waiting for it."

(Pratchett, 1991)

Space therefore has a reciprocal relationship with energy-matter. It *is* the communicative "presence of absence" or super-conductor (because it has zero resistance) that *connects* the insides and the outsides of "things", because it inhabits both *at the same time*.

Looked at from this perspective, the limitations of discretist and positivist views that seek to clearly define objects from their contexts, become clear. If space permeates through systems, connecting insides with outsides, it is simply not possible to sever that which is inside of something from that which is not. To return to an earlier metaphor, if one were to try to use imaginary scissors to separate an "object" from its context, one would have arbitrarily to divide the space along some imaginary line. And of course by doing this, one destroys one of the key features of the system – the implicit, and invisible communication between the object's inner context and its outer context, or environment.

In Inclusional thinking, as they are in complexity theory, boundaries are key. Inclusional boundaries, like the boundaries in complexity theory are not finite linear entities. But unlike in complexity theory, where boundaries are viewed as specific locations where important phenomena occur, in Inclusionality, boundaries are primarily considered to be manifestations of information both distinguishing and coupling inner contexts (contents) with outer environments. Importantly, Inclusional boundaries are both permeable and dynamic. They are continual reflections of the reciprocity between inner and outer spaces, which in any real system is also dynamic.

Inclusionality also has implications for the way we understand communication. As far as people are concerned, an Inclusional view of communication could relate to our dialogue, and to our actions with regards to other people, beings and environments. The same principles apply here as in other areas of Inclusionality. Namely, a new view of space, an understanding of the reciprocal relationship between inner and outer contexts, and a need to recognise that permeable, dynamic boundaries are all-important. I shall examine the Inclusional view of communication later in this thesis, but first (in the next chapter), I shall discuss how the perspectives I have introduced here have influenced the development of theories and models of *communication.*

Chapter 3 - Communication theory

3.1 Introduction

The work of past researchers of communication theory has influenced both the development of my own theoretical model and my practical research. So before I elaborate on my own work, I shall introduce the origins and development of communication theory, demonstrating how we have arrived at some of the models that are considered important today. This account is my own, drawn from a variety of sources; the texts that I have drawn from most extensively include Cobley (1996), Silverman (2001) and Littlejohn (2002). My account is however a partial one, and does not seek to provide an exhaustive guide to the development of communication theory. Rather I have chosen to highlight those parts of communication theory that are, I feel, particularly relevant to my own research.

One particular aspect of communication that has played a significant role in my study is *metaphor.* While it forms part of the wider literature on communication, metaphor itself has been much studied, to the extent that is has developed into a subject in its own right. Consequently, and because it has played such an important role in my own work, metaphor will be dealt with in a separate chapter that follows this one on communication theory.

The way *meaning* is generated is one of the leading questions in communication theory; this will therefore be a central theme in my discussion. The development of models of communication, from the relatively simple, to those that are more complex, follows a more or less chronological sequence. So, I too shall present the models ordered roughly by the time that they were developed, beginning with a discussion of the work of the language specialists who introduced the subject of *semiotics* in the early 1900s.

3.2 Model 1 – meaning in the words: language and semiotics

3.2.1 The signs specialists: Saussure and Pierce

The early work on human communication theory began with a focus on *language*, and on how language is used to generate meaning; meaning is believed to be engendered by the words themselves. The first serious work in this field appeared in the early 1900s with the development of the field of *Semiotics*.

Ferdinand de Saussure, a French linguist working in the early 1900s, was one of the first to develop a semiotic theory (Saussure, 1916). Working in the same domain and at much the same time was Charles Sanders Peirce, an American philosopher/logician, who developed models that were related to, but somewhat different from those of Saussure (Peirce, cited by Littlejohn, 2002).

Saussure developed the idea that a language is a system of *signs*, where words are used to *signify* objects. The language itself is an abstract system, which can exist independently from real-life objects. It is through the spoken or written word (Saussure used *parole*) that language systems are applied to real-life situations (Saussure, 1916). Saussure argued that no *actual* link exists between the sign and the object; rather it is an interpretative, or arbitrary link. Saussure also argued that words (or signs) in a language become connected into large communicative units, such as sentences and paragraphs, according to relations between the words. The way that this is done is determined by a "sign system", or set of grammatical rules (Cobley, 1996).

Peirce's *semiotic* model was similar to, but more complex than Saussure's. Peirce's model also became more strongly associated with American thinking on semiology, while Saussure is more often represented in European works on the subject. According to Cobley, the principle distinction between Peirce and Saussure is that Peirce's model is based on theories of logic, philosophy and mathematics, rather than on linguistics alone (Cobley, 1996). A key feature of Peirce's semiotic theory is his creation of three semiotic categories, which he named: firstness, secondness and thirdness. The precise meanings of these categories are too complex to explain fully here, but in essence, Peirce described *semiosis* as a relationship between a *sign*, an *object* and an *interpretant* (or meaning) (Cobley, 1996; Littlejohn, 2002). Since there were three categories, which were each related to each other, they could be represented in a triangular fashion, as shown in Figure 3.1.

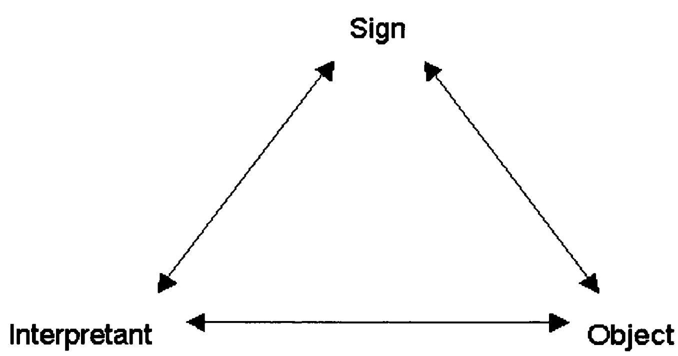

Figure 3.1 Peirce's notion of the triangular relationship between an object, what it is signified by, and how this is interpreted.

So, concurrently, but independently of each other, Saussure and Peirce developed a line of thinking that treats languages as *sign systems*, which are governed by *rules.* For languages such as English, the rules take the form of grammar, syntax etc. Similarly in visual languages, such as signing for the deaf, the rules take the form of sequences of gestures/hand actions etc. each of which has specific meaning. The rules of each sign system form *coding* systems. In languages such as English we have grammar books and dictionaries that prescribe the coding schema. Cohan and Shires suggest that the relationship between sign system and code is analogous to that between driving and the Highway Code (Cohan and Shires,1996).

Cohan and Shires also point out that the rules of a language system are only applied to real-life contexts through *discourse.* In discourse, the rules of the sign system may be broken, or adapted. So, if language is the *code*, discourse represents the real-life *application* of the code. Saussure was the originator of this line of thought, as he made a distinction between "language" (*langue*) and "speech" (*parole*) (Saussure, 1916). Cohan and Shires develop this idea to suggest that *meaning* is only developed through the application of language through discourse (Cohan and Shires, 1996). Discourse, they say, consists not only of the spoken words of a language, but also the nuances of verbal articulation, and of non-verbal communication such as body language.

Saussure recognized that one role of communication is to convey meaning between minds. Nevertheless, it does seem to me that his approach was deeply rooted in a classical analytical worldview. Both Saussure and Peirce treated language as being made up of distinct units - words, sentences and so on. These units, they argued, could be studied independently of their "real life" contexts, as systems in their own right. This view, I believe, reflects the reductionist approach to studying phenomena, where objects are removed and studied in isolation from their environments.

3.3 Model 2 – meaning in the transfer of information: systems and cybernetic theories of communication

3.3.1 Systems theories of communication

Although semiotics still exists as a field of linguistics today, many other approaches to human communication have been developed after Saussure and Peirce. Systems theory was one field of study that played a significant role in the development of communication theory. Up until the time that Bertalanffy, Wiener and others developed systems and cybernetics theories, much of the focus in human communication studies had been on language, linguistics and semiotics. With the advent of these new systems viewpoints however, communication systems were re-considered in a new light: as integrated systems. Significantly, *human* communication was no longer dealt with as entirely separate and distinct from other communicative processes. Systems theory treated human communication in the same manner as all other communicative processes, be they engineering systems (such as telephone systems), physical communication phenomena such as light or energy transfer processes, living biological systems, or entire social systems (Bertalanffy, 1968). These new systems theories made little distinction between the precise communication *processes* that were involved in these different kinds of system, rather they looked at the overlying principles of communicative transfer and the influence of communicative relationships within systems.

Bertalanffy argued that communication often concerns the flow of *information* within a system. He suggested that in many cases, although not always, the flow of information relates also to a flow of energy (Bertalanffy 1968). Bertalanffy also maintained that communication can be treated like any other system, containing features such as feedback processes and other aspects of control theory (Figure 3.2).

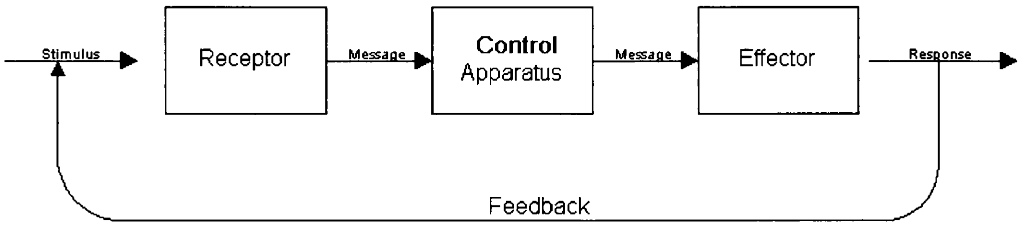

Figure 3.2 Simple communicative feedback scheme (after Bertalanffy, 1968).

Wiener, one of the founding fathers of the field of Cybernetics, also regarded feedback processes as highly significant in communicative systems. Like Bertalanffy, Wiener argued that the fundamental principles of communication are the same regardless of whether one is dealing with man-made machines and systems, or living organic beings; indeed he argued that human society itself is bound together by the same kinds of communicative principles as any other system (Wiener, 1948). Weiner maintained that communication is one of the principle means by which systems are coupled to their external environments; and if a system communicates with its external environment, this is one of the features which identifies is as an open system, rather than closed.

3.3.2 Information theory

In 1949, Shannon and Weaver, inspired by developments in systems theory and cybernetics, introduced a new communicative model that they called *"information theory"* (Shannon and Weaver, 1949). In information theory, information is viewed as a measure of the *entropy* or uncertainty in a system. In the information theory model of communication, a *source* produces a *message*, this message is passed along a *channel*, to a *receiver* that interprets the message.

The channel has *bandwidth* that affects the level of information that can be transmitted; bandwidth is a measure of communicative *capacity*. For example, in modern terms, if we connect to the Internet via a modem, its bandwidth affects how fast we can download data. A channel's bandwidth may also be limited by the form that the communication has. For example, when speaking on a telephone, the channel is limited to audio-only data; visual information isn't communicated. Wiener points out that the effectiveness of communication in such a model is dependent on quality of channel. A high quality channel transmits only the information that the sender communicates, whereas a poor quality channel may be contaminated by extraneous information, or what Wiener referred to as *background noise* (Wiener, 1948).

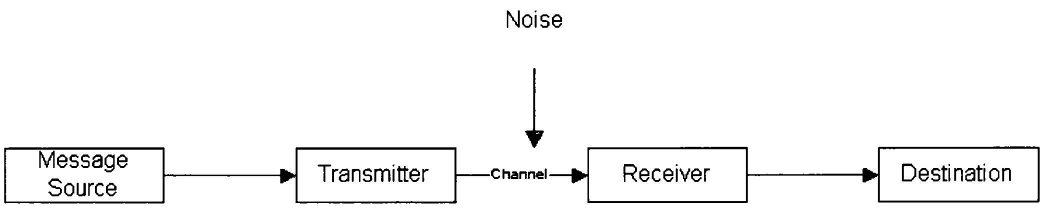

Figure 3.3 Shannon and Weaver's information theory model of communication (diagram after Shannon and Weaver, 1949).

In the information theory model, meaning is in the *message*; this message transmits from point to point in a linear fashion, self-regulated via feedback loops between source and receiver. This concept of meaning was taken to an extreme level of analysis by Osgood, who developed a mathematical model for finding where meaning is located. Osgood created the concept of "semantic spaces", which are effectively cognitive locations of meaning, and analysed the relationships between these spaces through a process of "factor analysis" (Osgood, 1957).

Shannon and Weaver's information theory has had a significant influence on the development of communication theory. There are however a number of drawbacks to their model. Significantly, the information theory model disregards the influence of *contexts* and *environments* on communication. It assumes that all communication travels from *point* to *point*, either from one source to one receiver, or from many sources to many receivers. Rather than being viewed as contextual influences, extraneous information is considered to be *noise*, which the receiver must filter out in order to discern the meaning of the message. Essentially, Shannon and Weaver's information theory reflects a cybernetic view of communication that is entirely focussed on "nodes" (speakers and hearers), which are connected only to each other and not with their contexts.

As I mentioned in Chapter 2, Shannon and Weaver's model has been respecified in terms of biology by Atlan, (see Atlan and Cohen, 1998). Atlan argues that unlike in the engineering systems that Shannon and Weaver were originally working with, where they considered noise to be extraneous information that must be filtered out, in biological contexts the redundant information that creates noise is an essential feature. According to Atlan, in a biological system noise is an indication of background *complexity*, from which emergent features may arise. The background complexity essentially comprises redundant information, but without this redundancy in the system, the mutations which lead to evolution could not occur. Atlan has therefore adapted Shannon and Weaver's original model so that some aspects of a natural system's *context* has been accounted for.

Atlan's model also subtly shifts the location of *meaning* in communication. In Shannon and Weaver's original model, meaning was in the *message* alone. By contrast, as Atlan explains, in his model, meaning is "never intrinsic to the message; the meaning is in the relationship of the message to some reference point outside of the information borne by the message". In other words, meaning arises not only from the information in the message itself, the also from the process of its transmission and the *context* in which the message is interpreted.

3.4 Model 3 - meaning emerges through dialogue between speakers and hearers

3.4.1 Conversation studies

Starting in the 1960s, and based in part on Information Theory concepts, a new approach to human communication began to be developed. In this new approach the focus is on what happens in conversational speech; it is based on the principle that meaning in communication is co-created between speakers and hearers through their dialogue. It is the *interaction* of the speakers and hearers that generates meaning in their communication. Since the models that apply this approach are concerned mostly with human dialogue, I shall refer to them as "dialogic models".

A key feature of dialogic models of communication is their view that human communication is governed by conversational "rules". The philosopher H. Paul Grice was a major proponent of this view, which he first presented in a series of lectures at Harvard University in 1967 (Taylor and Cameron, 1987). Grice argued that a conversation is a co-operative event, whose structure is organized by the speakers according to implicit and unspoken rules. Grice called these rules *conversational maxims*; he identified nine of these, organized into four general categories (Figure 3.4).

Grice's Conversational Maxims.

1. Quantity
   - i) Make your contribution as informative as is required (for the current purposes of the exchange)
   - ii) Do not make your contribution more informative than is required
2. Quality
   - i) Do not say what you believe to be false
   - ii) Do not say that for which you lack adequate evidence
3. Relation
   - i) Be relevant
4. Manner
   - i) Avoid obscurity of expression
   - ii) Avoid ambiguity
   - iii) Be brief (avoid unnecessary prolixity)
   - iv) Be orderly

(Grice, 1975; as cited in Taylor and Cameron, 1987)

Figure 3.4 Grice's conversational maxims

On first appearance these rules seem to be broken in practically any real life dialogue. This however seems to be the particular point that Grice was making, as he argued it is when the rules are *not* adhered to, or *broken* that we may learn most about how conversation works. For example, if someone says, "It's raining cats and dogs", they are apparently breaking the rule of "do not say what you believe to be false" (Littlejohn, 2002)[1]. When one understands, however, that the speaker has used a *metaphor*, the rule holds, and the conversation makes sense.

3.4.1.1 Turn taking

Turn taking is a feature of conversation that has had much attention from dialogue researchers. Sacks, Schlegoff and Jefferson identified a "turn-taking mechanism", by which those engaged in conversation negotiate who takes the turn to speak (Sacks *et al,* cited in Taylor and Cameron, 1987). According to Sacks *et al*, in any conversation a "turn" is identified by who holds the floor (i.e. the person whoever is speaking at any given time). The speaker whose turn it is has the *right* to speak, and also the right to transfer the turn should they wish to do so. This transfer may be indicated by a "current speaker selects next" technique, for example a speaker may transfer a turn by asking a question, such as: "What do you think Bob?" Other ways a turn may be transferred are through a new speaker interrupting the current one, or if the current speaker simply ceases to speak, so that his turn ends. In both these latter turn-switching mechanisms, the next speaker *self-selects* by choosing to take the next turn themselves.

Sacks *et al* suggest that one of the main mechanisms by which turn-exchanges are negotiated is through "adjacency pairs". An adjacency pair is a pair of utterances where the first utterance, spoken by one speaker, is naturally followed by the second, which is spoken by a different speaker. An example is the "greeting-greeting pair", where the first speaker greets another, while simultaneously handing over the turn in the expectation that the second speaker will use his turn to return the greeting. Other common adjacency pairings include:

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[1] "Throwing the baby out with the bath water" might be a better example, as the origin of the phrase "raining cats and dogs" is not actually a metaphor, but of mythological derivation (Jack, 2004).

- Question - Answer
- Offer - Acceptance/rejection
- Request - Compliance/protest/refusal
- Order - Obeyance/protest/refusal
- Accusation - Admittance/confession/defence/denial

(after Rosengren, 2000)

3.4.1.2 Common ground

Another concept that is often referred to in dialogical models of communication is that of *Common Ground* (Clark and Brennan, 1991; Wardhaugh, 1985). To establish "common ground" in dialogue means to set the context for one's communicated message. For example, if two people are meeting for the first time they will probably spend a proportion of their conversation time exchanging information about where they are from, what they are doing there, whether they have anything in common with the person they are talking to. Eventually they will resolve how much of what they have to say to each other they have in common, and how much they have to explain so that the message can be understood. This is known as "grounding". Other examples include describing a situation that someone may or may not know about, by using grounding questions a speaker can establish how much the person they are talking to already knows about the topic, and how much they need to explain, as in the dialogue below:

Joe: You know Mary was at the party the other day?
Fred: What party?
Joe: Jane's party, you know the one that you couldn't go to.
Fred: Oh yes, what happened?
Joe: Well Mary got really drunk, you should have seen it…

When Joe asks whether Fred knew Mary was at the party, he is trying to establish how much Joe already knows, and how much he needs to explain. Fred asks "What party?", so that he can work out what situation Joe is talking about, and his answer to Joe confirms that they have established the common ground in terms of talking about the same event. The message doesn't appear until the last statement, when Joe passes on the information that Mary was drunk.

According to Wardhaugh (1985), it is hardly ever necessary for speakers to treat each and every conversation as if the speakers are starting from the beginning with no shared knowledge at all. Often it is assumed by speakers that a certain amount of ground is shared through what he terms "common knowledge". The extent of this shared knowledge, says Wardhaugh, is affected by the circumstances of the speakers. For example, two physics researchers will assume a different level of common ground, to the knowledge they share with non-physicists. Nonetheless, even when we apparently share specialised knowledge with others, we do have to take care when referring to things outside of our shared specialised areas of knowledge. To quote Wardhaugh directly, "we cannot rely on others knowing what we know" (Wardhaugh, 1985).

For this reason, to establish what is shared knowledge and what is not, most conversations involve a degree of repetition and checking up that one has been understood. In dialogic models, these "checking" procedures are considered important not only for grounding purposes, but to check that one is being understood in general. One such method of checking is the "back channel". A back channel refers to the way that people acknowledge the communication that they are receiving. Examples include interjected comments such as "oh I see", "ah", and "hmm?", or body language or expression such as nods, grimaces and frowns. Back channels are classic means by which *feedback* occurs in communication. If a speaker receives a positive response from the hearer via a back channel, such as a nod, or a smile of acknowledgement, they will believe that their point has been understood, and continue with their utterance. If, however, they receive a negative response, such as a frown, or a verbal utterance such as "huh?", they will know that they have not been understood and that there is a need to restate, or expand upon what they said.

3.4.2 Conversation analysis

So, dialogical models propose that human communication is based upon pre-determined *rules*. These models, suggest that communication could be analysed for adherence to the rules, and have therefore paved the way for the development pf practical methodologies for communication research. One such methodology that has become widely established is "conversation analysis" (often referred to by the acronym CA). According to Silverman, conversation analysis is a way of describing "people's methods for producing orderly social interaction" (Silverman, 2001).

Sacks, who with Schlegoff and Jefferson developed the concepts of turn-taking, and other conversational rules, gave a series of lectures in 1964 and 1965 that prepared the foundations for conversation analysis as it stands today (Bull, 2002). Significantly, in these lectures Sacks argued that talk could be studied as a system in its own right, independently of other processes. He also claimed that ordinary everyday talk is organized according to structural and social rules, and that no detail in conversation, no matter how small, should be overlooked.

Sacks *et al* were also influential in the development of CA methodologies (Taylor and Cameron, 1987). For example, they developed a method of transcribing recordings that was phonetic, and which took into account non-verbal utterances. Subsequently, transcription processes have been the focus of much attention, as there are many different ways it can be done, so today, transcription is considered to be an important part of the CA process.

According to Silverman (2001), one significant feature of conversation analysis is that it centres on talk as data. Moreover, *only* the data that are directly derived from talk are used for analysis. Assumptions are not made about the motivations, orientations or backgrounds of the speakers, unless they arise as a direct result of analysing the talk that has been recorded.

In terms of the practicalities of how CA is done, Silverman mentions the following features as some that conversation analysts may look for in their data:

1) Turn-taking and repair
2) Conversational openings and adjacency pairs
3) How "institutional talk" builds upon the structures of ordinary conversation

The final point, regarding institutional talk, highlights one of the ways that conversation analysts try to deal with *contexts* in their analyses. As Silverman points out, although CA is centred on the *content* of the data, it does appreciate that the context of the data may also play a role in communication (Silverman, 2001). The CA approach suggests that, while conversational structures are not necessarily entirely dependent upon context, it may have an influence. For example, certain situations are conversational "institutions" that guide and direct the kind of language and conversational forms that may be used. Examples include courtrooms, TV interviews, workplace situations etc. Silverman says that the communication in these "institutions" is shaped by certain constraints, and these situations are often associated with particular ways of reasoning.

3.4.3 A critique of dialogic models

Although dialogic models are no longer explicitly about the "transfer of information", which is the way that Information Theory deals with communication, I would argue that they are similarly rooted in cybernetic models of communication. Through their searches for turn-taking rules, conversation-repair and so on, they are seeking cybernetic features such as "control factors" and "feedback loops". This, however, means that some of the problems inherent in the cybernetic paradigm are also apparent in dialogic models. Most significantly, there is no implicit connection between the communicators and their environments, or contexts. A number of workers have explained that context is not *excluded* from dialogic models, for example the concept of "Institutional Talk" in conversation analysis explicitly seeks to connect communicators with their contexts (Littlejohn, 2002). However, the fact remains that for context to be a factor in these dialogic models, it has to be explicitly *added* or *re-instated*, rather than being regarded as an inherent aspect of the system.

3.5 Model 4 - meaning emerges through co-relation between communicators and their social contexts

3.5.1 A holistic approach

Many communication researchers think that communicative meaning lies much deeper than in dialogue alone. Rather, they believe that meaning in communication arises from the *relationships* between communicators, their dialogue and their contexts; it emerges from the interactions between communicators, society, culture, history, environment, dialogue, and whole raft of other factors. I touched on this view earlier in my discussion of Atlan's work. Others have expressed similar views, for example, Budd and Raber say that:

"Meaning [...] has formative aspects that include the linguistic, the social, the political, and others." (Budd and Raber, 1996)

The term that has been applied to this broader concept of communication is *discourse.* Discourse has been defined as a three-dimensional concept that encompasses language use, the communication of beliefs and social interaction (van Dijk, 1997). Van Dijk suggests that if we are to explain discourse, we need to look not only at the structure, production and effect of our *language*, but also at the relationships between our *discourse* and the *society* of which we form a part (van Dijk, 1997). Littlejohn meanwhile goes further than this; he says that anything that is created through human interaction could be studied from a communication perspective. Human endeavours such as architecture, clothing, literature and so on are all expressions of people functioning and communicating in a social world. These different forms of expression also vary according to the social context in which they have been created (Littlejohn, 2002).

3.5.2 Discourse analysis

Discourse then, could be understood to be a term for any socially situated communication. To study discourse from this perspective therefore, requires a more *holistic* approach than for other methods such as conversation analysis. The study of discourse requires consideration of *contexts*, whether they be social, cultural or temporal. This perspective has been developed into a methodology for the practical study of discourse, known as *"discourse analysis".* According to van Dijk, who is a specialist in discourse analysis, "*discourse studies are about talk and text in context*" (van Dijk, 1997)

A key feature of discourse analysis is that it works with "texts". A text may be a written piece of communication, such as a story, a journal entry, or a newspaper article, but it can also represent verbal communication, since the spoken word can be transcribed (as was mentioned earlier with regard to conversation analysis). Rather than being broken down into "utterances" as in conversation analysis, these texts are usually studied in their entirety, as whole units of communication. The analyst is looking for patterns in the data, such as what social functions the text achieves, or how an argument is structured.

At the core of discourse analysis is the concept of "versions". According to discourse analysis, people create "versions" of their world through their discourse. These versions are distinguished by variations in language. For example, the courtroom record will form one analysable version of a case, the transcript of evidence given by a witness will form another, while the account of a member of the public in the audience will form another. All these versions will say something not only about the event itself, but also about the situation and perspective of the producer of the text.

The range of different materials that can be analysed through discourse analysis can be extremely diverse. While conversation analysis relies on talk as its data source, discourse analysis can be much more catholic with regards to analysable materials. Journal entries, or newspaper articles may become subjects for discourse analysis, as may transcripts of television programs, radio interviews, and even web page content. This means that discourse analysis could cover subjects such as the rhetorical structure of the media, or the patterns of communication in Web forums. So, while discourse analysis may not focus on the *detail* of conversational talk (such as pauses, "um's" "uhuh's" etc.) in the way that conversation analysis does, it has the potential to be far more broad ranging in scope.

3.5.3 A critique of discourse analysis

Unlike semiotics, which is concerned with reducing language to its *components*, or information theory and conversation analysis, which take a cybernetic view of communication, discourse analysis deals with whole systems. It treats language, society and cognition as irreducibly interrelated, and to study one aspect of discourse, one must take account of the others. What we are seeing in discourse analysis then, is a *holistic* view of communication.

The implications of the holistic viewpoint were introduced in the previous chapter, where it was pointed out that, while a holistic view obviates some of the problems associated with reductive analysis, it is not without its own limitations. In communication theory, discourse analysis is a holistic approach. With its focus on "versions" as irreducible whole accounts that are inseparable from their contexts, it is my view that discourse analysis severely limits the scope of applicability of one's findings. Every "version" of a discourse exists as an irreducible, and unrepeatable account. This means that, in the extreme sense, the findings from the analysis of each and every version can *only* apply to that version; they cannot be extrapolated to other versions of events as these too are unique.

We may learn something by comparing analysis of different versions of the same event, for example, things may be learned by comparing the text produced in a judge's discourse with that of the defendant. But even so, the results still apply only in a very specific sense to "courtroom" discourse, and more widely applicable patterns of communicative structure may not become apparent through this kind of analysis.

Another issue is that of *validity* of the analysis. There is a recognised risk that in qualitative analysis of the kind conducted in discourse analysis that researchers might "cherry pick" data to support their theorising, but which is not necessarily representative of the overall situation. Silverman (2001) discusses a number of ways in which the question of validity can be addressed. One method, suggests Silverman, would be to analyse the entire dataset, rather than selected excerpts. Yet often this is impractical because of the large volume of data involved in many discourse studies. Another method is to monitor the applicability of one's findings about one part of the dataset to its wider context, through a process of back checking and cross-comparison throughout the analysis. This, says Silverman, is known as the "comparative method" and ensures that the researcher has assessed whether their assumptions about the data have wider application, or whether they are restricted to a particular instance in the dataset. Yet another method that Silverman describes is to actively seek out cases in the data that deviate from the pattern one is trying to describe. Comparison between the deviant and non-deviant cases can, suggests Silverman, strengthen the validity of the analysis.

In overall terms however, I feel that the discourse analytic approach is limited by the way it fails to distinguish *boundaries within* a communicative system. Only one boundary is identified, that of the entire system. Smaller units within the discourse system, such as choice of words, structuring of sentences and so on, are given less emphasis, indeed they are regarded as insignificant in comparison with the contextual influences on dialogue. While this may tell us much about the context of the dialogue, this information about context is perhaps gained at the expense of knowledge of structural detail of the dialogue, and indeed at the expense of detail on how structural relationships in dialogue emerge through the co-relation of speakers.

3.6 Conclusions – an Inclusional view of communication?

Earlier in this thesis (Chapter 2), I suggested that philosophy has provided us with a variety of contrasting models, or perspectives on how the world may be studied: these include the classical analytical view, the systems or cybernetic view, the Holistic view, and newly emerging approaches such as Inclusionality. In this chapter, I have demonstrated that models of human communication have followed similar patterns of development, from Semiotic models that represent classical analysis, to information theory and dialogical models, that are part of a cybernetic view, to discourse analytical views, which are holistic in approach. Perhaps notably however, an Inclusional view of communication has not been discussed here. This is because, until now, Inclusional models of communication have not been developed beyond a basic level. Developing a model of communication that was based on Inclusional principles has been one of the key goals of my research. Therefore, the model that I have developed, which is a fluid network-based approach, has been dealt with in depth in a chapter of its own (Chapter 6).

Before discussing Inclusional network models of communication however, it is necessary to introduce another topic, which has profoundly affected how I have developed this thesis. The subject I am referring to is *metaphor.* As I am about to explain, metaphor can be viewed both as a communicative tool, and as a model for communication itself. Although it could be encompassed within the wider domain of communication studies, in recent years metaphor has been the focus of much research attention in its own right. For this reason it also merits a chapter of its own, and is the topic I shall discuss next.

Chapter 4 – Metaphor

4.1 Introduction

I began this study wishing to find parallels between human systems such as business organizations, and biological systems. In this thesis I am developing a line of thought that uses communicative processes seen in natural systems to suggest a model for human communicative systems, and indeed for communication in general. The essence of what I was trying to do at the outset however remains the same; I was taking knowledge from one domain and applying it in another. I was creating a new *metaphor* for understanding communication.

So, since I have been working with a metaphor, it would be useful to look more closely at how metaphorical thinking affects our perception of an issue, and how these metaphors may come into being. I shall begin with a look at how the contemporary theories of metaphor have developed, with an introduction to and critical discussion of the nature of metaphor as investigated by researchers in linguistics, psychology and organization science. I shall move on to discuss how metaphor can "frame" our thoughts and affect the way that we act and react in the real world. Finally I shall illustrate in detail how different metaphors may alter our perception of a system, using two distinct metaphorical paradigms – the mechanical metaphor, and the organic metaphor.

4.2 Theories of metaphor

4.2.1 Linguistic theories of metaphor

"Metaphor: a figure of speech in which a name of descriptive word or phrase is transferred to an object or action different from, but analogous to, that which it is literally applicable."

Oxford English Dictionary

The study of metaphor is by no means a new subject. Aristotle wrote of the capacity of metaphor to bring "clarity and charm" to poetry and prose, and warned that the use of inappropriate metaphors may cause confusion. Until the field of linguistics really began to be developed in the early 1900s however, metaphor was mostly regarded as a poetic device, something that could be used to make language "pretty" (Blasko, 1999).

With the advent of linguistic and dialogical models of communication however, researchers began to consider metaphor in a new way, as a subject in its own right. Initially, metaphor was studied only from a linguistic point of view, so most of the early work on the topic concerns how metaphor is generated through language. Searle brought together this work in a review published in 1979. In this review, Searle argues that metaphor is primarily a linguistic phenomenon, processed by the brain as language, and that the processing of metaphorical or figurative language takes more time than the processing of literal language (Searle, 1979).

One of the issues that seems important to linguists who have studied metaphor is that of meaning. They focus on questions such as "What is the meaning of a metaphorical utterance?", "Is the true meaning of a metaphorical statement the literal meaning of the words themselves? Or does the statement mean what the speaker wanted it to mean?". Searle believes that metaphorical expressions mean what the *speaker intended* them to mean (Searle, 1979). This may seem like a trivial point, but it has had a significant influence on the way linguists study metaphor. As Searle points out in his review, unlike in a literal and other non-metaphorical expressions, the speaker's meaning in a figurative or metaphorical expression is *not the same* as the literal meaning. How then does the hearer work out what the speaker's meaning is? Searle identifies a sequence of three stages that a hearer goes through to interpret a metaphorical statement.

i) Firstly the hearer has to recognise that the statement is figurative, rather than literal. He usually does this by working out that the literal meaning of the statement is not true. To use Searle's example, the statement "Sam is a pig", is easily proven untrue. But it isn't always that simple. Take Searle's next example, a quote from Disraeli who said, "I have climbed to the top of the greasy pole". How do we know that he didn't actually climb a greasy pole? Searle suggests that we know because of the *context* of the statement. When we listen to certain speakers, or know more about the context of the speaker, then we are on the lookout for metaphorical forms of speech. An example is when we read Romantic poetry, which is littered with metaphor. The reader, who is aware of this, knows to be on the lookout for figurative language.

ii) Searle's second stage of metaphor interpretation involves the hearer finding a possible alternative meaning for a statement that he has deduced is figurative. This is done, says Searle, by the hearer going back to the metaphor (X) and working out what features X has that might be present in the subject (Y).

iii) The third stage, is when the hearer goes through the possible features of X that he has deduced in stage ii, and works out which of them the speaker probably meant to apply to the subject, Y. This says Searle, is a complex process, affected by factors such as context, prior knowledge and shared knowledge, or common ground. But when it works, the metaphor is understood.

Searle explains that metaphors tend to *add more* meaning than a literal description. This he claimed, is because the interpretation of figurative language involves the hearer in a much more *participative* way than for literal language. To understand a figurative statement, the hearer has to process the statement according to the stages described above, whereas a literal statement can be understood in a much more passive manner. Searle argues that this is why metaphors often have more expressive impact than literal language, as the hearer is much more involved in the process of recognition and understanding of the context of the statement.

In contrast to Searle's step-by-step analysis of how metaphor is understood, Rohrer (1995) favours a parallel model of meaning making in figurative language. Rohrer rejects Searle's sequential model because he believes that it would take longer in real time than parallel processing. This, he says is supported by evidence from other researchers who have shown that, in most cases, comprehension of metaphorical language takes no longer than of literal language (Rohrer, 1995; Blasko, 1999). Rohrer favours a model where meaning-making in both figurative and literal language is one and the same process. He suggests that figurative meaning interpretation is probably not localised in one region of the brain, and this, he concludes, means that the model could only be substantiated after other kinds of investigation, such as neurological studies of what's happens in the brain during language interpretation.

Rumelhart (1979) is in agreement with Rohrer on the parallel nature of figurative language processing. He says that:

"The distinction between literal and metaphorical language is rarely, if ever, reflected in a qualitative change in the psychological processes involved in the processing of that language."

Rumelhart demonstrates this with a description of how children naturally shift between literal and figurative language. When a child can't find an exact word or phrase to express what they want to say, they often use an alternative figurative phrase instead; for example, the child who describes a "nasty smell in her tummy". The child uses a figurative term purely because their vocabulary does not yet contain sufficient words to express literally everything they want to say. But this also shows that the language processes involved in figurative speech are the same as for literal speech. A child doesn't stop and think "I'll use a metaphor because I don't know the right word", it's a natural process, and Rumelhart surmises that the process used by adults is exactly the same.

4.2.2 Cognitive theories of metaphor

In the early 1980s, George Lakoff and Mark Johnson published a radical new model of metaphor that challenged the established thinking on the subject (Lakoff and Johnson, 1980). They introduced the concept that metaphor might not only be concerned with language, but also about the way we *think*. Indeed they suggested that making metaphors is a *cognitive* process, and is something that the human brain does naturally. According to Lakoff and Johnson, our thoughts are *shaped* or *framed* by metaphor. Our brains work by relating new knowledge to old, and we are constantly looking at things *as if* they were something else. When we encounter something new, we ask ourselves "have I seen something like this before?" The model that Lakoff and Johnson proposed suggested that the whole way we understand and relate to the world is metaphorical, and that linguistic metaphor is just a surface reflection of the deep level of cross-domain linking that happens in our minds.

Lakoff and Johnson's model then is as much to do with psychology, cognitive science and communication theory as with linguistics. In his (1992) article on "The Contemporary Theory of Metaphor", Lakoff cites Michael Reddy, a linguist who specialized in communication theory as one of his primary influences. Reddy had written an article in 1979 titled "The Conduit Metaphor". Reddy's Conduit Metaphor asserts that communicators are "containers" and that communication acts as a conduit along which information is passed from one to the other. It is, suggests Reddy, based upon the principles of Information Theory and Cybernetics, which treats communication as a transfer of information between a source and a receiver. The conduit metaphor, says Reddy, has become part of common parlance in the form of some of the metaphors we use to describe communication, for example: "Getting an idea across", "Getting through to someone" and so on. Reddy maintained that this view of communication theory has strongly influenced the way we think about and work with language itself; the conduit metaphor of communication is a *cognitive model*, but that this was rarely acknowledged by theorists at the time.

Lakoff points out that Reddy's article was the first instance where someone showed that "the locus of metaphor is thought, not language" (Lakoff, 1992). Lakoff agreed with Reddy that conceptual models such as the conduit metaphor may have a profound effect on the way that we relate to the world, as well as on how we construct our language. Lakoff, however, took this idea further, and proposed that there are actually *many* conceptual models upon which we build our understanding of the world, and that we use in our communication with others. Some of the other mappings or metaphors that Lakoff presented were: LOVE AS A JOURNEY (for example, "we've reached a dead end in our relationship"); TIME AS PASSING MOTION OVER A LANDSCAPE (for example "Christmas is not far off"); AFFECTION IS WARMTH (e.g. "she is a warm-hearted person").

How did Lakoff reach this new model? He explains it thus: If metaphor were merely a case of semantics, then each metaphorical phrase would have different origins (Lakoff, 1992), and phrases such as "we've hit a dead end in our relationship", or "look how far we've come, we can't turn back now", would each form a separate metaphorical mapping. These examples, however, clearly share a common conceptual origin – that of "love as a journey". It was this realisation that prompted Lakoff to hypothesise that metaphorical phrases could actually be surface reflections of a deeper level of metaphorical mapping. Lakoff set out on a search for further examples to confirm this theory; and he found so many more mappings that he concluded that metaphor is not only about words, it reflects the way we *think*. We speak in metaphor because our minds work by transferring ideas from one conceptual domain to another: When we speak metaphorically it is because we think in metaphor.

It is not only obviously figurative language that reflects our metaphorical turn of thought. A great deal of our every day thinking is based on metaphorical mappings (Lakoff, 1992; Lakoff and Johnson, 1980). Indeed, Lakoff claims that *any* thought that is to do with abstractions or emotions is usually metaphorical. Following this argument, it might appear that pretty much everything we say, do or think is metaphorical. This is quite a disturbing concept! If everything is a metaphor of something else, where did we start? Is there nothing that is not a metaphor? Fortunately, logic dictates that not *everything* can be metaphor. Some things are experienced and conceptualised literally. Lakoff explains that non-metaphorical concepts are the ones that are based on physical experience (Lakoff, 1992). So, to quote his examples: "The balloon went up" is not metaphorical, neither is "the cat is on the mat". They are direct observances, and there is no transfer between conceptual domains.

Lakoff's work caused a sea change in the field of metaphor research. Prior to the publication of the book titled "Metaphors we live by", which he co-authored with Mark Johnson in 1980, metaphor was studied primarily as a linguistic speciality. After the publication of Lakoff and Johnson's contemporary theory of metaphor, there was a change of focus away from linguistic study of metaphor and toward the notion that metaphorical thought is a cognitive process that pervades our everyday cognition (Blasko, 1999; Stern,2000).

The principle feature of Lakoff and Johnson's theory of metaphor is that it identifies metaphor as being a *transfer* between two conceptual domains, or subject areas: the source and the target. This has become known as the "two-domain mapping model" of metaphor. This model is widely acknowledged as being the first move away from exclusively linguistic studies of metaphor. However, in recent years the model has been adapted and expanded to reflect new thinking in the area.

4.2.3 The conceptual blending model

In 1995 Gilles Fauconnier and Mark Turner published a *multi domain* model of metaphor. Although they do not entirely reject Lakoff and Johnson's two-domain model, they do propose that it exists within a framework of a larger model. Fauconnier and Turner call theirs a "many space model" (Fauconnier and Turner, 1995). Unlike Lakoff's model of discrete conceptual domains, where metaphor is generated through transfer between different domains, the many space model proposes that metaphors are generated in non-specific "mental spaces". These mental spaces are areas of consciousness that hold existing ideas or representations of an object that may be real, imagined or otherwise constructed by a speaker. A single mental space can represent multiple conceptual domains. *Mappings* are created between the spaces to create new conceptualisations, including metaphors.

Fauconnier elaborated on the many domain model in his book titled "Mappings in thought and language" (Fauconnier, 1997). In this book, he again reiterated Lakoff's view that metaphor is deeper than language alone, and that our use of metaphor reflects the way our minds work.

According to Fauconnier, the process of metaphorical cognition can be described as a number of stages. The first stage concerns the *induction* of analogy. When we use a metaphor, for example, a “computer virus”, we apply a *schema* from one domain to another. So, for the concept of a computer virus we connect the framework that we already have about viruses, (including perhaps ideas that concern health, disease, the spread of a disease, something that can't be treated easily), onto our mental domain that relates to computers. But the mapping, initially at least, only goes as far as making structural similarities, we do not necessarily make detailed and technical parallels between the two domains; we do not necessarily expect to treat computer viruses in exactly the same way as human viruses.

The second stage of metaphor creation concerns *categorization*, and the creation of a new conceptual structure. The mapped domain doesn't actually determine how we think of the existing domain; it simply helps us to build new ways of thinking about it. Also, if reality prevents us from building this new domain, the metaphor may break down as it is proven that it “doesn't work”. For a computer *virus* the metaphor does work quite well. Yet even in this example, the mapping mostly works at a high level; at a more detailed level the computer technicians rely on their own specific tools to deal with viruses.

The next stage in Fauconnier's model of metaphor creation is that of *naming*. By transferring *names* of things from one domain to another, we are no longer talking about one thing “as if it were” another, rather we are actually saying it *is* the other thing. This means that the metaphorical mapping has (to use Fauconnier's own words) “become entrenched in our conceptual and grammatical system”. This:

a) makes the mapping less obvious at a conscious level, so that it becomes unconscious and more natural in use
b) establishes the metaphor as a model for reasoning and new thinking about the target domain

The final stage is one of *conceptual blending*. Eventually the two categories become blended so that, for example in our computer virus example, virus means *both* a biological virus and a computer virus. They are both now seen as “the same kind of thing”.

At first, it may seem that Lakoff's Two Domain model and Fauconnier's Multi-space model are in conflict, since one proposes that there are distinct conceptual domains, and the other proposes shared conceptual "areas", Grady *et al* (1999), however, suggest that they are not actually incompatible. Rather, the two models demonstrate two different means of making metaphor. Lakoff's model deals with stable metaphorical relationships that remain held within long-term memory. While Fauconnier's model demonstrates how new metaphors are created, and permits that these metaphors may be dynamic and transitory in nature.

4.3 Metaphorical framing

We have demonstrated then that metaphor is intrinsically connected to cognition. It is therefore not a great leap to surmise that the metaphors we use may actually help *frame* the way we think about the world. Haste writes that our use of metaphor is deeply connected to our models and understanding of the world (Haste, 1993). An example that Haste suggests is the Cartesian dualistic model, which in Western thinking has become metaphorically "mapped" onto many areas of thought, causing us to think in terms of polarities. Things must be either one thing or the other – right or wrong, good or bad, black or white, etc. Metaphors such as these may become deeply ingrained into the fabric of our daily lives. For example, there are many relics of the mechanistic metaphor in our everyday language. We talk about things "working like clockwork", "getting back on track", or "running smoothly".

According to Allbritton (1995), our minds organize conceptual metaphors into knowledge structures or "schemas", which influence the way that we use metaphor. These schemas can act as filters for information, hiding or minimising features that don't relate the different topic domains, and highlighting the ways in which they are similar.

Stern demonstrates that the metaphoric schema that one employs can radically affect the way one thinks about a subject (Stern, 2000). Suppose, suggests Stern, that one has a neighbour who is nice, quiet and polite. He keeps himself to himself, doesn't bother anyone, doesn't cause any trouble, and generally doesn't attract attention to himself. Then one day we learn that this neighbour has been arrested as a suspected spy. This radically affects the way that we think about him. Now, rather than being seen as someone who is merely quiet and perhaps a little ordinary, he may become in our minds a cold, calculating and threatening person, or we may see him as a clever character with an exciting double life. Whichever view we take, our view of the man is altered, and our beliefs about him are considered in a new light. We might look back over our memories of this neighbour and remember past encounters with him in a new light. We might remember perhaps that he always seemed to be interested in electronic gadgetry, which at the time seemed simply eccentric, but is now explained by his secret occupation. This new way of thinking about our neighbour "the spy", says Stern, has caused us to think about him differently. We have applied a new metaphor or *schema* onto our old knowledge about something, and it has caused us to restructure and reorganize our beliefs

Ritchie suggests that the way that a particular metaphor is interpreted depends on the amount of common ground that is shared between the speaker and the hearer (Ritchie, 2004). The details of how a metaphor is interpreted depends on the situation, historical contexts of the communicators, and so on. Ritchie demonstrates this with an imagined conversation between two old friends who have not seen each other for a long time. During the conversation, one of them says "my wife is an anchor". How this comment is interpreted by the hearer depends on what he already knows about his friend and his friend's relationship with his wife, as well as on any new information that he's just learned. To quote Ritchie directly, it could mean: "you seem a lot happier than the last time I saw you; you used to be discontented and easily distracted, now you seem much more settled and at peace with yourself". Or it might be interpreted as: "You sound like you have become bored with life; you used to be eager to try new things, but now the old zest for life seems to have become dulled."

Sometimes, says Ritchie, a metaphor is only treated in our minds as a superficial likeness between one conceptual domain and another. This may be the case if the metaphor makes immediate sense, or if the tempo or context of the communication means that deep analysis of a metaphor isn't possible. In many situations, however, metaphors are actually processed very deeply. According to Ritchie, metaphors are often a means of making connections between pre-existing webs of ideas and concepts in our minds. In this manner, suggests Ritchie, metaphors can open up new and subtle connections in thought and feeling between different conceptual domains.

Chia (1996), has expressed similar views about the way that metaphor can unlock new ways of thinking and communicating. Chia wrote on the process of "metaphorization" and how it affects our way of thinking, arguing that, not only does metaphor affect the way we think about things, it also has a special function as a communicative tool. Metaphor, says Chia, allows us to use language more economically, and it also allows us to describe things that could otherwise not be described using literal language. Metaphor alludes to that which is intangible and hard to express in words. Chia's own words beautifully describe the illuminating effect of metaphorization, in a statement which seems to me to be reminiscent of an inclusional perspective he writes:

"Metaphors, by speaking of what remains absent, draw our attention to the significance of the empty spaces between literal concepts,"

This property of metaphor, suggests Chia, means that it can be both disturbing and positive with regards to our pre-existing language and ideas; metaphor challenges us to reconsider hitherto taken-for-granted ideas. To quote Chia again:

"metaphorization [...] is the endless intellectual task of de-ossifying thought."

Ossification is the biological process of laying down bone. By referring to metaphor as having a "de-ossifying" effect, Chia is suggesting that metaphor can break down entrenched structures that have become established (or laid down) over long periods of time. From this, it becomes obvious that not only is metaphor a means by which we *frame* our understanding of the world, but it can both *promote* and *communicate* paradigm-shifts, causing us to radically rethink previously entrenched ideas.

4.3.1 Metaphors and models

Some researchers have made a distinction between that which is merely metaphor, and metaphorical frameworks that have become developed into *models* (Eliasmith, 1998; Hill and Levenhagen, 1995). Eliasmith, says that there is an important conceptual difference between model and metaphor: a metaphor or an analogy, leaves room for interpretation by the hearer, allowing them to make their own connections between the source and target domains (Eliasmith, 1998). A model, however, does not allow for any such interpretation; Eliasmith refers to a model as a "controlled metaphor", where every aspect of the relationship between the model and reality is accounted for. So, for example, if a scientist were to say: "the atom is like a solar system" it would allow hearers to interpret this in their own way, and to generate their own mental imagery. A model, however, would consist of a diagram, a prototype, or a mathematical description that allowed no room for interpretation by the hearer, other than the one that the scientist explicitly intended.

Hill and Levenhagen point out a similar distinction between metaphors and models in organizational management (Hill and Levenhagen 1995). In organizations, say the authors, mental models provide frameworks for how things should fit together; they highlight certain features within an organization, such as underlying values, shared interests and understanding. An model provides a framework for an organization's policy, rationale and core cultural values. Like Eliasmith, Hill argues that a *metaphor* is not the same as a *model*. A model provides a complete and formalised framework upon which an organization may operate, while a metaphor merely represents a simplified or incomplete allusion to that model. Metaphors are, however, the means by which models are produced. It is through use and development of a metaphor that a model becomes formalised.

4.3.2 Metaphor as a tool for transdisciplinary study

So we have seen that metaphor has the power to *frame* and even direct our thoughts. We shall now look briefly at how metaphor may be used as a communicative tool, or as it is often referred to in the literature, how it may be used as a communicative *vehicle* (Judge, 1991).

Petrie and Oslag (1993) describe how metaphors may used to help students learn, by using a student's prior knowledge as a metaphor for new information. This is using metaphor in a very basic sense, as described at the very beginning of this chapter: taking knowledge from one domain and applying it in another. Petrie and Oslag explain that what one is actually doing in teaching using metaphor, is to use an existing "schema" that the students already understand, to teach them about a new subject.

It is immediately obvious that using metaphor as a "vehicle" for communicating new ideas in this way may have application other than in the classroom. For example, one could also use metaphor to transfer knowledge from one subject domain to another. Bohm and Peat have discussed this idea in their book on creativity in science (1987). Bohm and Peat suggest that particularly in science, metaphor can act as a tool to cross barriers between disciplines. Moreover, they suggest that communicating across disciplines in this way can be highly beneficial, as it encourages scientists to consider old information in a new way.

Like Peat and Bohm, McGregor also describes metaphor as a transdisciplinary tool (2004). Reflecting Reddy's conduit metaphor, McGregor suggests that metaphor may be used as a *passageway* that allows people to transfer knowledge from one domain to another. Moreover, McGregor emphasises that the *spaces* between disciplines are also interesting, and rather than continually trying to *cross* these spaces, it is far more useful to *explore* them, as the areas between disciplines are often fertile ground for the development of new ideas. It is in these spaces, suggests McGregor, that metaphor may come into its own as a communicative tool, to use her own words, creating a "temporary common language while we navigate between the disciplines".

4.4 Metaphor in the everyday world

4.4.1 Metaphorical schemas and human organizations

In recent years, there has been a trend toward overtly using metaphorical schemas to understand and work with *human* organizations. An early proponent of this approach was Gareth Morgan, who in 1986 published a book, titled "Images of Organization", which was to become much quoted both by management and metaphor specialists. Morgan argued that when we apply metaphorical schemas to human organizations, they deeply affect the way we understand and act within them. In "Images of Organization" Morgan discussed a number of different metaphorical schemas, including "organization as machine", "organization as brain", "organization as living organism" and "organization as political system". In later literature on the topic, some have suggested that Morgan's approach is somewhat simplistic, as some of his metaphorical schemas are not developed beyond a fairly superficial level (Mangham, 1996). Nevertheless, his original text prompted many to reconsider how they think about human organizations, and is still frequently referred to in today's literature.

In the concluding sections of this chapter, to further demonstrate how metaphors can frame the way we think about the world, I shall introduce some of the literature that has dealt with the effect of particular metaphors on our understanding of human organizations. I shall begin with the Cartesian/Newtonian machine metaphor, before moving onto organic or living systems metaphors, and will conclude with metaphors from the non-linear sciences, to include complexity theory and network theory.

4.4.2 Machine metaphors

As I discussed in Chapter 2, the mechanistic worldview is rooted in the works of Descartes and Newton. The machine metaphor has origins in this worldview, and treats systems and organizations as giant *mechanisms*, comprising parts that work together to make a functional whole. Machine metaphors were amongst the earliest to be applied to human organizational management, and even today, now that other viewpoints such as organic and non-linear systems models have gained popularity, the machine metaphor remains deeply engrained in many institutional regimes and processes, and even in our language. For example, when we speak of things "running smoothly", or "ticking over", we are using a machine metaphor.

Frederick Winslow Taylor was one of the most prominent amongst those who started the "organization as machine" metaphor in the early twentieth century (Lewin and Regine, 1999). In 1911 Taylor published a book titled "The principles of scientific management", which became influential in the development of mechanistic approaches to organizational management. Taylor took the prevailing mechanistic view of science and translated it into a form for use in the workplace. Above all else he sought to make organizations more *efficient*. He used reductionist analysis to determine *laws* and *rules* for the workplace that could be applied to both machines and to human workers. Taylor made little distinction between the human and non-human parts of the organization; indeed he viewed human workers as parts of the machine itself. His goal was to improve the efficiency of each and every part of what he considered to be an entirely mechanical system. According to Lewin and Regine, although Taylor's model has changed much over the intervening years, it is still the dominant management model today (Lewin and Regine, 1999).

When the mechanistic viewpoint is applied, it has profound implications for the way that we view and act within the world. Notably, when a system is viewed as a machine, the implication is that it is under the *control* of someone or something. Machine metaphors are associated with hierarchical structures, where someone or something, situated at the top of the hierarchy, has ultimate control over the system.

Rooted in the reductionist paradigm, the metaphorical “machine” is composed of parts, that each have predictable cause and effect relationships with the other parts. Unlike in an organic paradigm, where systems may “run themselves”, under the machine metaphor all events are initiated by another part (Haste, 1993). As a result of the strong cause and effect relationships, a system that is running under a mechanistic metaphor should run in a *predictable* fashion, and when something in the system goes wrong, the belief is that it should be possible to put it right by looking for a root *cause.*

According to Morgan, the machine metaphor can, and has worked successfully in the past, particularly in organizations that are concerned with mass production of identical products, are situated within a stable “environment”, and where the human elements of the organization are compliant (Morgan, 1996). Nevertheless, Morgan also points out that organizations that are run on mechanistic principles tend to be slow to adapt to change, and they can have a “dehumanising” effect on their workforce.

4.4.3 Organic metaphors

The idea of using organic, or biological metaphors was introduced by Bertalanffy (1968), who was one of the first to suggest that living systems might be viewed as *open to their environments*, rather than as the closed isolated systems preferred by the Classical Analytical approach. Since Bertalanffy, many more have used organic, biological and ecological metaphors to describe human organizations. Books have been written on “Corporate DNA” (Baskin, 1998), the notion of a “Living Company” (de Geus, 1997), at one point Microsoft were even working to develop a “Digital Nervous System” (Gates, 1999). Other examples of biological and ecological metaphors applied to organizations include: *genetic algorithms* for process management (Husbands, 1994), and the punctuated equilibrium model of evolutionary processes applied to organizational learning (Price and Evans, 1993).

The organic metaphor is associated with a very different view of systems than the mechanical metaphor. By contrast with the machine metaphor, where all events are expected to be under the control of someone or something, in an organic metaphor, systems are considered to be autonomous or self-regulating. Under a machine metaphor, systems are based on linear hierarchies; organic metaphors, however, treat organizations as integrated systems of interrelated processes and relationships.

As Haste points out, organic metaphors are *participatory* (Haste, 1993); they situate the individual *within* the system. In an organic metaphor, people exist *inside* the system and are part of it, rather than being outside of it and controlling it as was the case with the mechanistic metaphor. Unlike in the mechanistic metaphor, where control and prediction are key, the emphasis in an organic model is on harmony, participation and creating balance through relationships with others. Significantly, unlike in the mechanical metaphor, where people are either treated as controllers, or as dehumanised parts of the machine, within the organic metaphor, people within an organization are seen as living sentient beings, with thoughts, characters and feelings.

There has been a clear trend in organizational management towards organic metaphors, and particularly towards models of organizations as members of complex "ecosystems" (Morgan, 1996). In an ecological metaphor, the organization is believed to exist as part of an ecological system, competing with others for survival according to the principles of Darwinian natural selection (Broekstra, 1996). According to Morgan, in an ecological metaphor, the key to survival for the human organization is for it to locate a specialist niche, and to become specially adapted for that niche, thus minimising the effect of direct competition from others.

Where an organization is viewed as a member of a complex "ecosystem", it is believed to act and interact within a wider context or environment which, for a human organization might encompass aspects of economics, sociology, politics and so on. To use a term from cybernetic theory: it is an *open* system. The organic organization also interacts with other organizations in its environment, and as they relate with one another, this brings about change and adaptation; this metaphor therefore emphasises the importance of collaboration. Morgan argues that this understanding of the relationship between organizations and their environments is one of the key strengths of the organic metaphor. Morgan calls this view "organizational ecology", and suggests that such a view helps us to understand the relationships between organizations and their environments.

4.4.4 Metaphors based on the non-linear sciences and network theory

In recent years a different organizational metaphor has begun to emerge. This metaphor is based on the new non-linear sciences, to include chaos theory, complexity theory, and most recently, network theory. I discussed the fundamental principles of the non-linear sciences in Chapter 2. To briefly recap here, in the non-linear sciences certain types of system, known as *chaotic* systems, are believed be extremely sensitive to initial conditions, to the extent that they appear to behave in an entirely unpredictable manner. Other systems, which are referred to as *complex* systems behave in a similarly unpredictable manner, but under certain conditions will exhibit *self-organizing* behaviour, spontaneously producing patterns that are *emergent*. Often these emergent patterns occur at the boundaries between a chaotic system and one that is ordered; these areas are referred to as the "edge of chaos".

Numerous authors have suggested that the non-linear sciences may be used as a metaphorical schema for human organizations (including: Lissack, 1997; Murray and Robson, 2002; Richardson and Lissack, 2001; and Battram, 1998). There is some debate as to whether complexity is a *metaphor* for an organization, or an actual representation of the *structure* of an organization (Murray and Robson, 2002). Many authors, however, choose to side step this issue and use complexity theory primarily as metaphor. And once again, like the other organization metaphors that I have discussed, the metaphor of "organization as non-linear system" highlights how a metaphorical schema can alter and *frame* the way we think about an organization.

According to Fairholm (2004), using the new sciences as metaphors causes one to think about organizations in terms of *relationship* and *culture*, rather than in terms of prediction and control. It also embraces the notion of boundaries that are semi-permeable, rather than solid as they are in the reductionist or mechanistic perspective, so creating a view where organizations are open and in communication with their environments.

Richardson and Lissack (2001), point out how using a complexity metaphor for human organizations requires managers to reconsider how they perceive *boundaries*. In a complex systems paradigm, the non-physical boundaries between people, teams, departments and so on, are considered to be as real and as significant as physical boundaries. Unlike the permanent and discrete boundaries of reductionist and mechanistic paradigms, in complex systems boundaries are emergent and temporary. This, say Richardson and Lissack, means that in a complex human organization, the boundaries of and within the organization are in constant flux, and the organization itself is undergoing constant reconfiguration. When using a complexity theory metaphor for human organizations, Richardson and Lissack suggest that the focus should be on organizational *coherence*, and that it is important for the people within to maintain a strong sense of organizational identity. According to Richardson and Lissack, this can be achieved through ensuring that those within the organization share common goals and viewpoints, and that they act together in a coherent manner.

4.4.4.1 Network theory metaphors

Most recently, researchers and managers have started to look towards *network theory* as a metaphor for use in human organizations (including Jones, 2004; Standifird, 2001; Pavlovich, 2003). The details of network theory will be discussed in the chapter that follows this. In essence, however, network theory is a novel paradigm emerging from complexity theory that seeks to understand systems by means of analysing the patterns of connection between nodes in a network. These nodes may be people, documents, web pages, computers and so on, and the connections between them may represent any of a wide variety of communicative relationships, from transactional exchanges, incidences of dialogue, connecting wires (in the case of computers), to name but a few examples.

In a world where globalized communication networks such as the Internet are rapidly gaining significance, network theory is increasingly being applied as a means of interpreting organizational structures and communication. Standifird has suggested that ideas from network theory may be used as a means of understanding institutional *rigidity* (Standifird, 2001), while Jones suggested that a network metaphor may be of particular use in *virtual* communities (internet communities, text message groups and so on), as these communities are in fact based around physical networks (such as, computer networks, phone networks) (Jones, 2004).

Recently, Pavlovich has proposed a particularly interesting application of the network theory metaphor (Pavlovich, 2003), where the dynamics of *jazz* music are treated as a form of network. According to Pavlovich, jazz is a fluid form of collective organization, where dynamic networks of musicians configure and reconfigure their organization according to apparently emergent patterns. Pavlovich noted how in a jazz performance, leadership of the group of musicians is self-organized, emerging fluidly over a basic rhythm that is co-created by the players. Rather than relying on hierarchical rules of leadership, the players often "switch" between soloist and supporting roles in an improvised and fluid manner. When jazz music works well, there is, observes Pavlovich a level of synchronicity, harmony and fluidity in their collective patterns. According to Pavlovich, the emergent networks of jazz music could be used as metaphor in human organizations, to create structures that are managed collectively and through fluid forms of leadership.

I shall discuss the practicalities and significances of network theory and the network metaphor in much greater detail in the following two chapters. Suffice it to say here that *conventional* network theory tends to focus on transactional relationships between nodes in a network, and the fluid metaphor described by Pavlovich is somewhat unusual in network theory.

4.5 Conclusions

To conclude, I have shown in this chapter that there is a lot more to metaphor than mere linguistics. Metaphor reflects the way we *think*, it has the power to *frame* our thoughts, and it may be used as a *communicative* tool, both within and between disciplines. Metaphor even has the capacity to promote shifts in established patterns of thought. The application of novel metaphorical schemas has been used as a means of changing the way we think about human organizations, and metaphor is today recognised as a powerful management tool.

To my mind, however, some of the more recent metaphors of organization are beginning to blur the boundary between *metaphor* and *model*. Complexity theory, for example, might be used as a metaphorical schema to apply the *ideas* of complexity to an organization, or as a means of describing the *structure* of an organization that exhibits complex behaviour. Network theory, which is the focus of my own research, is another example. The principles of network theory might be applied to an organization as *metaphor*, to try to understand the relationships within, or it could be used to create an organization that is *actually* networked. In fact, it might be argued that many organizations already *are* networks, and in these, network theory is less of a metaphor and more of a tool for description.

Nevertheless, irrespective of whether the framework we use is metaphor or model, it is still a tool that has the capacity to alter the way that we perceive a system. The newly-emerging models and metaphors that are based on network theory could, therefore, greatly influence the way that we understand an organization, and how we chose to act within it, or try to alter it. In the next chapter I shall explore the principles of conventional network theory in more detail, showing how they can frame the way we think of a system. I shall also point out some of the limitations of the conventional network model, and suggests that the organization of some kinds of network, particularly those found in the natural world, are not supported by such models. This will lead on to my own model, which I present in Chapter 6, which represents an entirely new structural and metaphorical schema that is based on living network forms.

Chapter 5 – Conventional network theory

5.1 Introduction

Network theory is currently the focus of a great deal of attention, both in terms of academic research, and in application in the non-academic world. Based on a combination of social network theory and mathematical models, conventional network theory treats networked systems as collections of interconnected *nodes*. In this chapter, I shall discuss the origins and development of this conventional theory of networks, and the manner in which it has been applied as metaphor to systems and organizations. I shall also discuss in some detail the inherent problems of conventional node-based network models, demonstrating how they can influence the way that we think about systems. This is however, a partial account and does not claim to be an exhaustive treatment of network theory. I have highlighted the aspects of network theory that are, I feel, most relevant to my own research and which exemplify the literary context surrounding my own ideas. The chronology and detail of this account are drawn from a number of sources, but principally from Barabasi (2003), Buchanan (2003), Littlejohn (2002), Scott (2003) and Watts (2004).

5.2 The history and development of conventional network theory

Network theory originated during the 1930s in the social sciences and was considered to be primarily a social science tool until the late 1950s when Cartwright and Harary (1956) connected network theory with graph theory and mathematics. After that point, the mathematical research into network structure continued at a steady pace, resulting ultimately in our contemporary and conventional network models. The network theory as it exists today, which includes "small worlds" models is based upon some fairly complex mathematical models, although the core principles are relatively straightforward to understand. Despite the underlying complexity of modern network theory, the subject has become immensely popular, and modern network theory has become applied in many different domains, from computer networks, to biological ecosystems, to business management.

The original work on network theory was conducted by an informal group of German psychologists who specialized in "Gestalt psychology". Gestalt psychology offers a direct contrast to the classical Cartesian/Newtonian approach, and was one of the precursors of the systems theory view. In subsequent years however, network theory has become much more conventionalised, as the whole systems theories of the Gestalt scientists became mapped onto the more classically based graph mathematics. As a result, network theory has the potential to offer an interesting insight into the way that a model may develop "between" worldviews. In practice however, and despite the cries to the contrary of many network specialists, who claim that it does take a whole systems view, modern network theory has much in common with the classical Cartesian/Newtonian worldview. The details of how this is so will become apparent in my critique of network theory, which appears later in this chapter. But first we shall consider how modern network theory came into being.

There are two main threads to the research that has been carried out on conventional networks. One, to which I alluded above, relates to human *social* networks, and originated during the 1930s. The other thread, which began more recently, concerns the study of networks as *structures*, and has lead to the development of *mathematical* models of network structure. These two threads have however become intertwined at stages during their evolution, with social networks informing the network structuralists and vice versa. With this in mind, I shall tell the story of the development of network studies on a single timeline, pointing out along the way how the approaches of the social scientists both differed from, and connected with the structuralists and mathematicians.

5.2.1 Social network theory

The psychologist, Jacob Moreno, was one of the members of the informal group of German psychology researchers, which first developed the concept of social networks. In 1937 Moreno published his own network model, which he used to analyse human social groups. Moreno was studying whether the psychological state of individuals within a group is related to the relationships between the group members (Scott, 2003). Moreno invented the "Sociogram", a diagrammatic representation of the relationships between people in a social group. Typically, sociograms consist of dots, or "nodes" that represent people, with the relations or connections between them represented by lines.

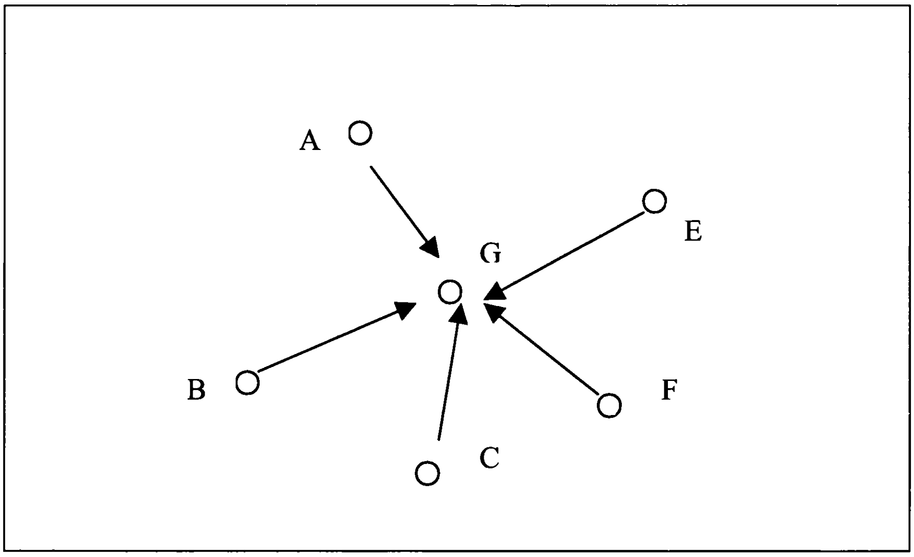


Figure 5.1. A typical Sociogram. Nodes represent people, arrows show the relationships between them.

Moreno's work initiated a line of research that dealt with the measurement of social networks, and which was ultimately to become "Social Network Analysis", a method for measuring and analysing social networks (Scott, 2003). The details of social network analysis will be dealt with in more depth in a later chapter of this thesis, as it is more concerned with practical methodology and analysis than with network theory. It is, however, worth noting here that the work initiated by Moreno psychologists branched off into two distinct threads at this point – the line that became focussed on social network analysis, and the line that was to become developed into contemporary network theory, which concerns much more than social networks alone.

5.2.2 Graph theory

The next significant development in network theory research didn't appear until some twenty years later, with the publication of a paper by Cartwright and Harary (1956). Cartwright was a sociologist, while Harary was a mathematician. Their paper made the claim that sociograms such as Moreno's could be analysed using a type of mathematics, known as *graph theory.* In mathematical terms, a *graph* is a structure or diagram consisting of points that are connected by lines representing the relations between them. Graph theory is a subset of mathematical calculations and formulae that describe these graphs. Up until this time, the social scientists who were working on sociograms had used *words* to describe the relations represented by their diagrams. The significant contribution of Cartwright and Harary was to link the hitherto entirely qualitative sociograms of social science, with the quantitative analyses of graph theory.

5.2.3 Six degrees of separation

In the late1960s, Stanley Milgram advanced network theory by a major step. Milgram, a Harvard sociology professor, was investigating what was colloquially known as "the small world problem", after the popular, but as yet unproven hypothesis that within a social group any person could contact any other person through a surprisingly small number of links. Milgram set about testing this idea through an ingeniously simple experiment. He distributed letters to 160 randomly chosen residents of Wichita and Omaha in the United States (chosen by Milgram because they seemed suitably remote places in the U.S). All the letters were addressed to the same person, a stockbroker in Boston, NY. Along with the letters, Milgram sent a sheet of instructions directing the random recipients to forward the stockbroker's letter either to the stockbroker himself (but only if they knew him in person), or to another person whom they felt was more likely than themselves to know him. Milgram wanted to find out how many steps on average it took for the letters to arrive. He suspected that this average would be a large number, perhaps as many as a hundred steps, and that if this was the case not many of the letters would actually arrive. By the deadline however, 42 of the 160 letters had arrived, and the average number of steps that the letters had taken was a mere six. Although Milgram's experiment applied just to the United States, his findings gained great popular appeal, even becoming immortalised much later in a play by John Guare (1991). The title of the play was "Six Degrees of Separation", and it was Guare who suggested that the six degrees rule might apply not just to America, but globally.

5.2.4 The strength of weak ties

In 1973 Mark Granovetter published one of the most influential papers to contribute towards modern network theory. It was titled "The strength of weak ties", and developed upon the "Small Worlds" hypothesis proven by Milgram (Granovetter, 1973). As part of his Ph.D. research, Granovetter had conducted a survey of successful job applicants, in the Boston area of the United States. He was interested in how these applicants had found out about their new jobs, and the contacts that they had made to become employed. In interviewing these people, Granovetter noted that in answer to his question about "whether the person whose information that led to a job was 'a friend'", often provoked the rejoinder: "No, just an acquaintance" (Barabasi, 2003). It was as a result of his findings, that Granovetter developed the idea that the significant links in a network are not the strong connections, but the weaker and more tenuous ones. He suggested that the strong ties within a network, for example those between close friends or family, who are frequently in contact with one another, are usually between mutually close groups of people. For example, in a family, there may be close ties between parents and children, and also between the children, in effect creating "triangulated" groups of strong links. Weaker links however, tend to connect *between* social groups. For example, we may have a friend who lives in New Zealand with whom we only make contact occasionally, perhaps just at Christmases. This friend however is likely to have an entirely different group of close contacts to our own, and our "weak" link puts us in connection with an otherwise far-removed social group; without this weak link, we might have no contact with these other people at all. In terms of job-hunters, Granovetter surmised that the close-knit groups of strong contacts were unlikely to provide opportunities of job prospects because they were in effect "closed"; they only have contact with each other, and the group is unlikely to be very large. Weak ties however put a job hunter in contact with a much larger network, where through tenuous links, they are more likely to encounter someone who they hadn't heard about before, who was looking to employ someone.

Granovetter's paper is also significant because he was the first to introduce the concept of the network *bridge*. A network bridge is one that connects between groups of close contacts that would otherwise be unconnected. This is exactly how the weak ties in a network act.

5.2.5 Watts and Strogatz' "Small Worlds" model

During the 1970s and 1980s, spurred on by the insights of Granovetter, the work on social networks continued, with researchers worldwide looking for small world phenomena in many different domains. Yet it wasn't until 1998 that another breakthrough in network theory was made, when Watts and Strogatz published a paper titled "Collective dynamics of 'small-world' networks". This paper was to become one the most influential in the history of network theory. Watts and Strogatz, both mathematicians at Cornell University in New York, had set about trying to find a *mathematical* explanation for the small world phenomenon, focussing in particular on the organization of the *graphs* of small world networks.

What they found was that small world networks are neither random, nor regularly organized. Rather, they lie at a point between the two extremes. What characterises a small world network is the presence of *random* long distance ties, that directly interconnect otherwise distantly connected nodes.

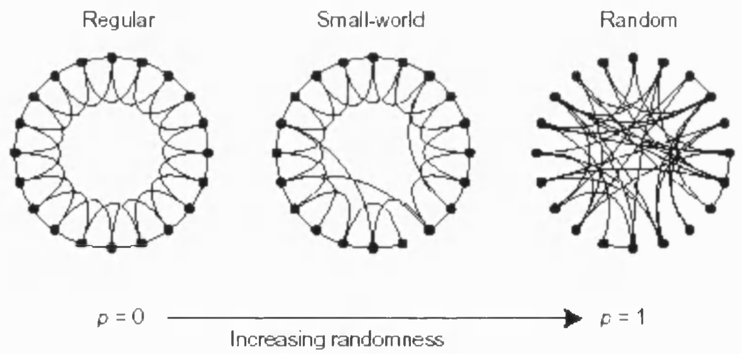


Figure 5.2 Different patterns of linking in regular, small-world and random networks (Watts and Strogatz, 1998)

One can immediately see a connection here between the findings of Granovetter, who identified the social importance of these weak, yet long distance ties, and the work of Watts and Strogatz, who identified the structural significance of these links.

After the publication of Watts and Strogatz' Small-World model, many other workers began looking for small-world structures. And indeed small-world structures were found in such diverse areas as language (Cancho and Sole, 2001), the World Wide Web (Albert *et al*, 1999), human sexual contacts (Liljeros *et al*, 2001) and cell metabolism (Jeong *et al*, 2000), to name but a few.

5.2.6 The significance of hubs

Currently, another key worker in the field of network theory is the physicist, Albert-Laszlo Barabasi (Barabasi, 2003; Albert *et al*, 1999 and 2000;Jeong *et al*, 2000). One of Barabasi's key contributions to the field of network theory is his work on the significance of *hubs.* As I explained earlier, Network Theory holds that networks are composed of entities, or "nodes" that are connected, with the connections between them being represented by solid lines. Through his research on the structure of the Internet (which he and his team had already discovered to have small-world structure), Barabasi found that in a small-world network there are often a number of nodes that are more *connected* than the others; they have far more lines connecting them with other nodes than the average node. Barabasi called these nodes "hubs" and postulated that they have greater significance than other nodes, since when they are removed from the network, the impact of their loss on the entire network is greater than nodes that have relatively few connections (Barabasi, 2003).

In terms of resistance to self-generated errors or minor internal failures, many nodal networks are actually quite robust. Research has shown that small-world networks are still able to function despite the deletion of many nodes, provided the nodes deleted are chosen at random (Albert *et al*, 2000; Callaway *et al*, 2000). If however, a targeted *attack* takes place that focuses on the hubs, the networks become very vulnerable; it only takes the removal of a small proportion of the hubs to cause the disintegration of the entire network structure.

5.3 Conventional network theory as a metaphor for systems and organizations

As I have mentioned, conventional network theory has now been applied in a great many different domains. In many of these situations it could be said that network theory was being applied as a *metaphorical schema* in these systems, that is to say, the systems were examined *as if they were* exhibiting network behaviour.

In biological science, network theory has been applied both on a macro level and on a larger ecological scale. Jeong *et al* (2000) studied the metabolic activities of biological cells. These researchers studied the internal metabolic processes of forty-three different species of micro-organism, and found that, not only were the patterns of processes in all the organisms structurally similar to one another, but also that the organization of these processes was structurally similar to that of non-biological "small-world" networks.

Meanwhile, Corner *et al* (2003) demonstrated that the spread of tuberculosis (which is transmitted through the air, like the common cold in humans) in a species of New Zealand possum, could be predicted through modelling the networks of social interactions between the animals.

In terms of human sociological behaviour, Newman demonstrated that the collaborative behaviour of research scientists may be described using network theory (Newman, 2001), while Liljeros *et al* (2001) have shown that on a sociological scale, human sexual behaviour may be described in terms of network theory. Liljeros points out that the actors in a social network who behave as "hubs" are significant, suggesting that the hub actors in a sexual network are likely to be those who are sexually promiscuous, and may be focal points within the network in terms of disease transmission.

Raab and Milward (2003), have made a distinction between overt, or "light" networks where people collaborate with the intention or ameliorating a problem or with other positive motives, and covert, or "dark" networks, where the motives are illegal or subversive. These authors looked at three kinds of "dark" network: heroin trafficking, networks of Al Quaeda terrorists, and military arms smuggling networks. They showed that these "dark" networks share some characteristics with "light" or overt networks. For example, both overt and covert networks share the same need for security. Covert networks, however, differ from overt networks in that they are structured according to the need for secrecy, and permit the use of physical force to achieve their goals. According to Raab and Milward, covert networks tend to be decentralized structures. They are also not as strongly reliant on hub figures as an overt network. Should a key figure be eliminated from a covert network (such as when a gang leader is captured and imprisoned), then there are usually others within the network who automatically fill his role.

In business organizations, network theory has been extensively investigated as metaphor. Morgan (1996), mentioned the use of networks as a metaphor for organizations. At that time however, Morgan suggested that the network metaphor fell within the wider model of "organization as political system". Within this political framework, argued Morgan, organizations may be seen as loose networks of people who gather together for a common purpose, such as making money, developing a career, or some other common objective.

In subsequent years, many more have investigated network theory, both as an organizational metaphor and as model for organizational design. I mentioned a few of these in the previous chapter, such as Pavlovich's (2003) "jazz" network metaphor. Others who have reviewed the state of research in the area include Borgatti and Foster (2003), and Palmer (1998), who both wrote detailed reviews on the use of network models in organizational theory.

Capra (2002) also proposes the use of a network metaphor within human organizations. According to Capra, the networks that exist within successful organizations are like natural living networks, such as those seen in natural ecosystems, which function as "self-generating networks of communications". Capra goes so far as to suggest that the "living network" structure might be viewed as more than a metaphor, and that organizations might actually be understood *to be* living systems. This idea is somewhat contentious, and goes further than the scope of my argument here, as I don't intend to explore deeply the boundaries between metaphor and reality in this thesis.

The network metaphor delves deeply into the way that we understand the structure of a system. Like the organic metaphor, conventional network structures are concerned with *relationships.* Conway *et al* (2001), explain that using network as metaphor in human organizations changes the imagery from a focus on *pairs* of dyadic relationships to one of *systems* of relationships. As in the organic model, metaphors based on conventional network theory are concerned with the way that the relationships within a network affect one another; it is realised that a change in one part of the network might affect other parts, and that the loss or gain of a single node might affect the whole network. Similarly, in conventional network theory the structures are non-hierarchical distributed systems. While some nodes may be more *powerful* than others, they do exist within a distributed system. Unlike in systems that have linear hierarchies, in a nodal network there may be alternative routes to a single node.

What makes the network metaphor distinct from the organic metaphor is the conceptual framework with which it is associated. The metaphor of "organization as network" is based on conventional network theory. Consequently, the network metaphor maps an established framework of concepts associated with network theory onto an organization. So, when applying a network metaphor, specialised network concepts may be brought into play. For example, a person in an organization may be viewed as a "hub" if they have contact with many other people. Or they may act as a "bridge" or "liaison" if other nodes need to communicate through them to reach the rest of the network.

5.4 A critique of conventional network theory

Clearly therefore, conventional network theory has become the focus of much research attention in recent years, and it continues to gain in popularity. As a research tool, conventional network theory can, and has been used to good effect for cross-disciplinary study. The appeal of the conventional network model is understandable. It brings orderliness to an apparently disordered world, reducing complex problems to a series of relationships that may be mapped diagrammatically. These diagrammatic maps may be analysed mathematically, often producing some neat answers, such as an indication of which nodes are more influential than others, or of how the network actually contains a number of sub-networks (Scott, 2003).

Nevertheless, conventional networks do have a number of inherent problems, which arise as a direct consequence of their topology and organization. Most significantly, conventional network theory is concerned *only* with nodal networks. Conventional networks are constructed from *components* that have been connected together. Like a schoolchild's chemistry model where balls with sockets are connected together with rods to represent a molecule, a nodal network comprises nodes that are connected together using point-to-point links. As we shall see throughout our discussion, this node-centred paradigm has had a major influence on the properties of conventional networks and the applicability of network theory. By comparison with the structure of *natural* networks, which I shall introduce in the next chapter, nodal networks are rigid and inflexible structures. This is so for both physical and conceptual nodal networks; a node-based organizational model brings about *inherent* rigidity.

The rigid nature of a node-based network is largely due the manner in which the focus, in conventional network theory, is on the nodes themselves. Nodes in a nodal network are *discrete* entities; they have finite boundaries that distinguish them from their surroundings. These are nodes that have been *abstracted* from their normal contexts. Conventional network theory represents any relationships that exist between these discrete nodes, by creating "links" between them. But, like the nodes, these links are also discretely defined; they are finite, point-to-point connections between otherwise independent nodes. The links don't branch, grow, bud, or flex. They go from *this point here* to *that point there.*

Think back for a moment, to Milgram's social experiment, which we discussed earlier in this chapter, where he asked American citizens to send letters to a particular stockbroker (Milgram, 1967). Milgram found that on average it only required connections between six people, six nodes on the network, to reach the stockbroker target. It was later discovered that this pattern also occurs in other societies and communities, such as the collaborative science research networks studied by Newman (2001), or in the Swedish "web of human sexual contacts" identified by Liljeros *et al* (2001). It didn't matter whether the target is a stockbroker, or a particle physicist, or a prostitute. Nor did it matter whether the context was American society, University research facilities, or Sweden – the small world structure was found in all of these contexts. The fact that small world networks can be found in such diverse environments suggests that the pattern may *not* be dependent on context. Does this not corroborate the argument that conventional nodal networks are fundamentally decontextualised from the start? One begins to suspect that it might be possible find a small-world network *anywhere*.

The problem is that while it might be useful to identify Small World relationships within a network, conventional network theory does not tell us much about a system as a whole. Nodal networks focus on the *relationships* between the nodes in the network, but not at all on the relationship between the network and its context. There is no inherent way of representing *context* in a nodal network model. In the conventional network model therefore, a significant aspect of the system has simply been excluded.

As I mentioned earlier, the nodal network model affects how we *think* about a network. One of the aspects of a network that is significantly affected by the nodal model is *communication*. In a nodal network the links that exist are all point-to-point; they reach from one node to another. As a result, communication in nodal networks is "transactional"; information is passed from one entity to another, via the lines that have been set out when the nodes were reconnected. This "point-to-point" communication mechanism is reminiscent of the Information Theory model of communication, which I have already discussed in Chapter 3. One will recall that in Chapter 3, I argued that Information Theory is a point-to-point model of communication, which, like conventional network theory, *abstracts* communicative processes from their contexts.

Another significant concept in the nodal network model is that of the *hub.* A hub is any node that has connections with more than one other node, and the hubs that are most highly connected act as focal points in a nodal network (Barabasi, 2003). According to Barabasi, nodal networks have robustness in the sense of being able to resist breakdown should the non-hub nodes be removed, but great fragility should the hubs themselves be taken away (Albert *et al*, 2000). It will become apparent when we discuss natural network structures, however, that hubs only have this significance in node-centred networks. Their pivotal role arises because the focus in a nodal network is *on* the nodes – so when one removes a key node, such as a hub, the effect on other parts of the network is great because there is nothing *to* the network other than decontextualised nodes and connectors. By contrast, as we shall see in the next chapter, many living networks are non-nodal flow-forms, rather than node based structures. When one removes a part of such a natural network the structure is usually flexible and resilient enough to be able to re-route flow around the damaged area, and even to forge new pathways that re-build the gaps.

The restrictions of the nodal network model also influence the network's patterns of growth and development. This again is a consequence of the rigidity of the lines that connect the nodes. The lines in a nodal network are always connected at either end to a node. The connecting lines only exist because they represent links *between* nodes, so they cannot end in "thin air". This means that the only way that a nodal network may grow is by the *addition* of new nodes. So for example, when a computer is added on to a company's Intranet (a classically nodal network), the new node (the computer) is connected to the network with a new link (an Ethernet cable).

Moreover, because the links themselves in a nodal network cannot branch, the network can only branch at a node point. This means that the pattern of growth in a nodal network is largely determined by the properties of the *nodes.* If a node has *capacity* for the addition of new links, growth at that location is possible, but if a node is fully populated with links, then growth at that node point must stop. A nodal network therefore has very little developmental plasticity. We shall return to this idea later, as it contrasts strongly with the natural network model.

5.4.1 The risks of applying a nodal network model to a non nodal system

The logic behind network theory is coherent and highly credible, and as a theoretical model of constructed *nodal* networks it produces some very rational explanations. The problem is that the answers provided by conventional network theory relate *only* to nodal networks, which means that its usefulness is limited. This is because, as I am about to explain in the next chapter, many naturally occurring networks are by contrast, *non-nodal* expressions of *flow forms.* There is a great risk that conventional network theory, based on nodal network structures, is being applied in situations where the structures are actually completely different. Where conventional network theory, with its node-centred analysis has been applied to living *flow form* networks, the result is often an erroneous picture of their organization, and indeed sometimes has the effect of causing them *damage.*

One such situation, where nodal network theory has been incorrectly applied to a living network is in the ecological concept of the "keystone species". The biologist Robert Paine was the first to introduce the term, in the late 1960s (Paine, 1966). At that time, Paine was studying the shoreline ecosystems of the North American Pacific Coast. In a pioneering experiment, he chose a specific predatory starfish species (*Pisaster ochraceous*), which feeds on mussels, and removed all individuals of this species from a small (eight metre by two metre) area of shoreline over a period of several years. The impact of doing this was significant. Initially, the area became colonised heavily by barnacles. Later these were crowded out by a species of mussel, and eventually the site became dominated by mussels. As a consequence of the mussels' grazing, most of the species of algae disappeared entirely. Over a period of several years, during which all of the starfish were removed, Paine found that the number of other species of organism in the community reduced from fifteen to a mere eight.

Paine surmised from this that all of these changes were provoked by the absence of the starfish, and that naturally they must play a vital role in the ecosystem. According to Paine it was the way that the starfish fed in patches that was most significant. Occasionally, the starfish would move into an area and completely clear it of mussels. However, because the starfish fed in a patchy manner, clearing only some areas, but never the entire population of mussels, over time the mussels would move in again to re-colonise the cleared patches.

Paine concluded that it was the predatory behaviour of the starfish that maintained the diversity and vitality of the community as a whole, and that is was therefore a "keystone species", as without it the ecosystem fell apart. Later, authors such as Pimm, who reviewed a number of ecological studies where other keystone species had been removed, found similar patterns. Pimm noted that indeed often when a keystone species had been removed, the entire ecosystem had not been able to survive (Pimm, 1980).

According to conventional network theory, a keystone species is considered to be like a *hub* within the ecological network (Dunne *et al*, 2002). It is believed to have more relationships within the network than most other species, and therefore, as a network hub, has considerable impact on the whole network should it be removed.

The problem with this is that it's potentially a small step from this view, to classifying all ecological relationships according to how much their loss is "noticed" if they are removed. In reality, ecological relationships are much more complex than this. In a biological system, each and every species is dynamically interrelated, not only with the other species present, but also with members of it's own kind, and of course with the environment itself. Indeed Berlow *et al* (2004), who reviewed a number of studies on ecological keystone species, pointed out that a species that is key in the relational topology of the network, may not necessarily be key in terms of biomass, or of population dynamics. They suggest instead that the role of a species is more complex than a single-factor relationship. It seems to me that to suggest that one species is more "important" than another in the complex network that is an ecosystem, takes far too simple a view, and utterly misinterprets the paradoxical strength and fragility of what is a highly interconnected and living system.

5.5 Conclusions

So, to conclude this chapter I have discussed how models arising from conventional network theory, such as Small-World networks, have been used as metaphor and model within a wide variety of domains. Typically, conventional network models have been used to identify and describe relationships of power, influence and so on. I have described how conventional networks are node-focussed structures that *diagrammatically* represent the relationships or transactions occurring between contextually abstracted nodes. I have discussed how the nodal network model affects the way that we think about a network, and argued that conventional network theory tends to frame our concept of "network" in a manner that is inflexible and which limits the possibilities for growth.

Conventional network theory doesn't, however, describe every kind of network that exists, and in the natural world, one may find physical networks that are organized quite differently. In the next chapter, I shall introduce my own network model, which contrasts strongly with conventional network theory. This model is based on the organization of networks found in the natural world, and, unlike the node-centred transactional networks of conventional network theory, it describes networks that are produced as a result of a system's responses to *flow*.

Chapter 6 – Natural networks: towards a new metaphor of networks formed through *flow*

6.1 The structure of natural networks

In recent years, conventional network models have become highly popular in the biological sciences. Network models have been applied in many different areas of the biological sciences, from ecology (Dunne *et al*, 2002), to cell biology (Jeong *et al*, 2000), epidemiology (Boots and Sasaki, 1999), and neuroscience (Sporns, *et al*, 2000), and others. In most cases, the network theory and analysis has been used to measure or represent *relationships* between parts of a biological system using node-focussed models. In these models, the nodes might represent anything from metabolic compounds (Jeong et al, 2000), to species in an ecosystem (Dunne *et al*, 2002), or neurons in a brain (Sporns *et al*, 2000), while the lines between these nodes in the network representation could indicate (respectively) chemical interactions, ecological relationships, or nerve signals.

In physical terms, however, many of the networks that actually exist in the natural world are structurally quite different from the networks described by conventional network theory. Unlike the node-focussed structures of network theory, which are collections of finite points linked together with connecting lines, many natural networks exist as systems of *tubes*, which enable their contents to circulate or *flow*. Examples of such networks include blood circulatory systems and the networks of veins in a plant leaf. The organizational features of the "constructed" nodal networks described by conventional network theory, and the tubular flow-managing networks found in the natural world are radically different from one another, not only structurally, but also in terms of communication, possibilities for growth, development, and many other aspects.

In this chapter, I shall begin by introducing a number of real-life examples of natural flow-managing networks and the literature that describes them as such. I shall discuss the organizational features of these networks in more general terms, showing how the patterns and structures found within natural fluid-managing networks demonstrate a new way of thinking about networks, one which is quite distinct from that of conventional network theory.

I shall also introduce my own new concept of a "flow-form network", which has emerged from my study of biological networks, which explains the structure and development of natural networks in terms of fluid transformations expressed within heterogeneous contexts.

The intention in this chapter is to present the organization of natural flow-form networks as both "metaphor" and "model" for how we might understand network topography and function. As I discussed in Chapter 4, metaphor has been described as a transdisciplinary device, where one thing is thought of as if it were another (Bohm and Peat, 1987; McGregor, 2004). The notion of a natural flow-form network could be usefully applied as metaphor to other, non-biological, communicative systems, such as business organizations. So if, for example, we think of a company *as if it were* a fungal network, we would be applying the flow-form network as *metaphor.*

The use of the flow-form network as metaphor is partly what I am proposing in this chapter. I do feel however, that the power of the flow-form concept can be more fully expressed when it is used as a *model*; that is to say, when the idea of a flow-form network is treated as a *representation* of how communicative systems are, or might be. As I shall discuss in this and later chapters, the flow-form network model could have profound implications for the way we understand communicative processes in any system. It suggests that rather than treating communication as a process of transition between discrete *states,* we could consider communication to be the result of fluid transformations. This is a new and radical approach, which has arisen largely as a result of considering communicative processes in the light of Inclusionality theory.

6.2 Networks in the natural world

So, what do natural flow-form networks actually look like, and where do they occur? Networks in nature are actually remarkably common, we only need to know where to look for them. Typically, networks in the natural world occur wherever there is a need for a *distributary* system. Many networks in nature comprise circulatory systems (blood systems, leaf venation patterns, insect wings and so on); (Figures 6.1 and 6.2). Other networks may be found where groups of animals or insects form trails, such as the foraging paths created by army ants, or the well-worn paths made by herds of grazing animals such as sheep or cattle (Figures 6.3 and 6.4). Many natural networks are *dendritic*, or branched in form, creating structures that look like the branches or a tree, or like the meandering pathways of a river, branching from large channels into smaller and smaller side branches.

Figure 6.1 Vein network in an ivy leaf. Photo: Karen Tesson

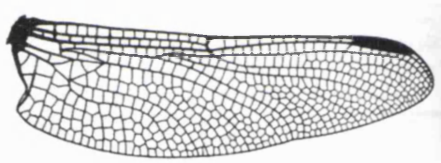


Figure 6.2 Venation on dragonfly wing. Image taken from Thompson (1971)

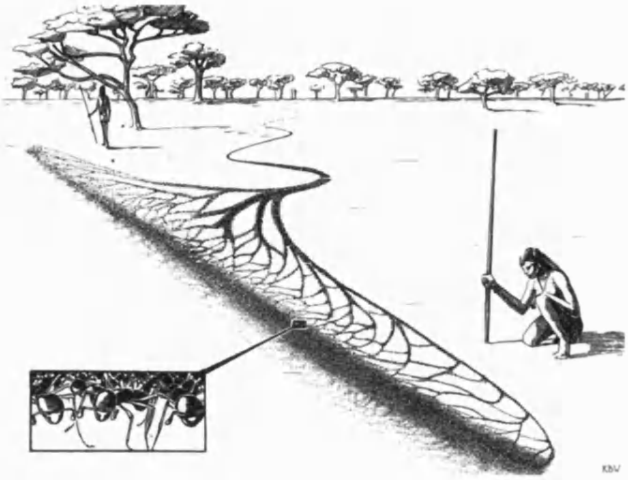


Figure 6.3 A foraging swarm of *Dorylus* driver ants produces a networked pattern. (A drawing by Katherine Brown-Wing, taken from Wilson, 1990).

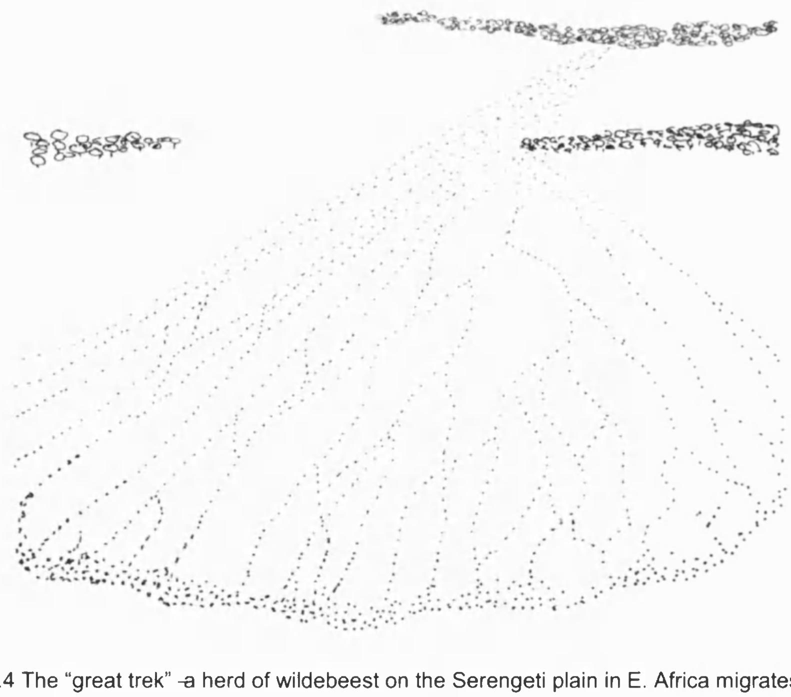


Figure 6.4 The "great trek" -a herd of wildebeest on the Serengeti plain in E. Africa migrates along well-worn trails towards river lands as the dry season advances (Rayner, 1997).

6.2.1 Previous research on natural network structures

The structure of natural dendritic networks has received much specific research focus. As I mentioned above, the vast majority of research on networks in biology has been focussed either on small-world network models, or on other conventional node-based network topologies. The search for past work that was specifically concerned with non-nodal networks has therefore lead to some of the perhaps less prodigious areas of biological research.

6.2.1.1 Leaf venation patterns

One kind of natural flow-form network that has been researched by scientists is leaf venation architecture. The veins in plant leaves perform two functions; one is to structurally support the leaf, while the other is to convey water and food (in a soluble form) to the leaf tissue. Leaf venation patterns are highly variable throughout the plant kingdom, to the extent that venation patterns are sometimes used to distinguish between different species of plants. Roth-Nebelsick *et al* (2001) have produced a comprehensive review of studies of leaf venation architecture, where they point out that there are two alternative forms of venation structure in plant leaves. The first, which is most usually found in simpler (and often more primitive) plants, is an *open* venation pattern. Here, the veins are arranged in a dendritic pattern, where the ends of the veins are not connected with one another (Figure 6.5). The second is a *closed* venation pattern, which is more commonly seen in higher plants. In a closed system, the ends of the veins are connected with one another, usually at the margins of the leaf, and so form a fully connected network structure (Figure 6.6). Roth-Nebelsick *et al* point out that in a closed venation pattern, the pressure of the fluid contained within is usually more homogenous than in open systems, since the fluid is able to flow around the network more freely. Another feature of the closed system, say the authors, is that is has *redundancy*. This, as we shall see later, is an important feature of all natural networks, where, if the branches are anastomosed (the technical term for branches that have fused), several pathways are available rather than just one. This, suggest Roth-Nebelsick *et al*, makes a leaf with a closed vein network more resistant to damage than one that has an open vein pattern.

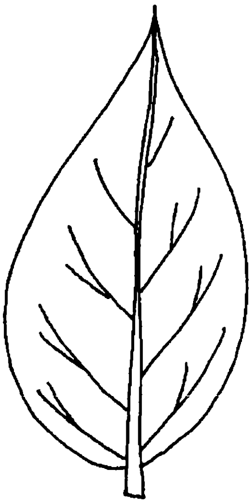


Figure 6.5 Leaf with open venation pattern

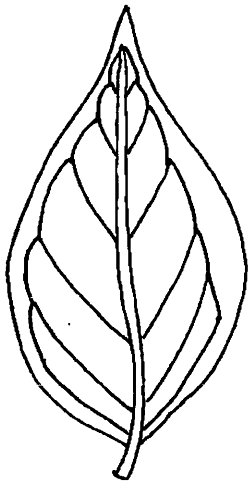


Figure 6.6 Leaf with closed venation pattern

Others working in this area include Pelletier and Turcotte (2000), who have discovered statistical similarities between river networks and leaves. They used the measure of the system's *fractal dimension*, which is a measurement originating in complexity theory of the space-filling nature of a surface.

6.2.1.2 Angiogenesis

Another research area that deals with non-nodal networks is *angiogenesis*. Angiogenesis refers to the formation of new blood vessels in mammals; typical situations where angiogenesis occurs include: during wound repair, in cancerous tumours, and during embryonic development of a foetus.

Typically angiogenesis begins as a response to chemical compounds that are released into the tissue that surrounds the wound, tumour or embryo (Alberts *et al*, 1994). These compounds diffuse through the tissue until they reach an existing blood vessel. Here, they cause the wall of the vessel to break down and to produce tiny finger-like "sprouts" that will eventually form new capillaries. These sprouts continue to extend, initially in parallel with one another, but later they begin to incline towards each other and eventually they anastomose, or fuse at their tips, forming a new capillary network. In tumour angiogenesis, it is at this point that the first signs of blood circulation appear in the new network (McDougall *et al*, 2002). The network then continues to sprout and extend until it reaches the tumour, at which point the capillaries penetrate the mass of cells and the tumour becomes vascularized; that is it gains its own blood circulatory network (McDougall *et al,* 2002; Alberts *et al*, 1994).

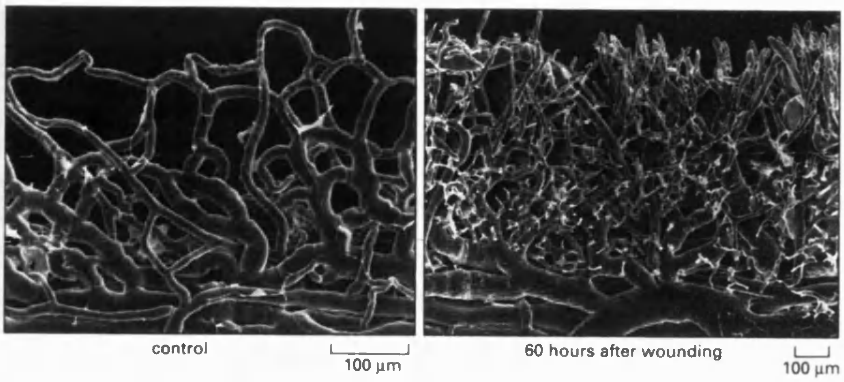


Figure 6.7 a and b, showing a capillary network, and a capillary network that has begun angiogenesis (sprouting). Taken from Alberts *et al* (1994).

Carmeliet has written a comprehensive review of the medical implications of angiogenesis (Carmeliet, 2004). In this review he cites a number of articles that describe the effect of internal pressure forces on the branching of capillaries during angiogenesis. As Carmeliet explains, pressure that is evenly exerted over the surface of the tubule causes the tube merely to expand, while pressure on the ablumenal (outer) side of the capillary causes it to branch.

Carmeliet also mentions that capillaries that have low levels of flow through them often regress or degenerate, and that for capillary branches to survive, the flow of fluid through them needs to be maintained. This, he suggests, is similar the fine-tuning of synaptic (nerve) circuits, where "appropriate" neuronal connections are strengthened, while "inappropriate" ones are eliminated. As we shall see later in this chapter, this is also a feature of other natural networks, such as fungal networks.

The actual flow of blood during angiogenesis has been studied by McDougall *et al* (2002), who used a mathematical model to show how drugs are transported into cancerous tumours via their newly formed capillary network. They found that the *structure* of the tumour network, particularly the density of the anastomosed links, was correlated with its capacity to deliver anti-cancer drugs to the tumour.

6.2.3 A natural network in detail: mycelial networks

The fungal mycelial network is a rare example of a natural network that has been researched in great detail. Fungi are ubiquitous organisms that are found throughout the natural world. By 1991, 70,000 species of fungi had been described, and it was estimated that perhaps 1.5 million species of fungi exist (Hawksworth, 1991). Fungal species range in complexity from single-celled yeast species, to those that form highly organized tubular networks. In fact, the structures that many people refer to as fungi, or "toadstools", are often only the visible fruiting bodies of a large and complex, but mostly hidden fungal organism, where the bulk of the fungus is hidden within the substrate in which it is growing, which may be wood, soil, leaf mould etc., in the form of a network of tiny fluid-filled tubes which are called *hyphae*. This arrangement of tubes is also known as a *mycelial network*.

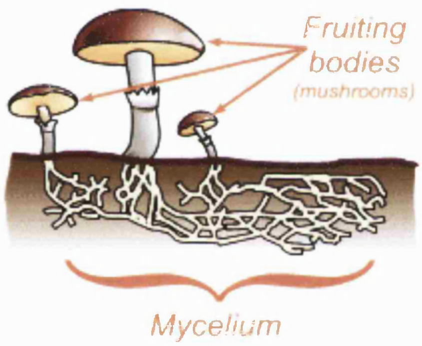


Figure 6.8 Fungal fruit bodies are the outer manifestation of a hidden network

Figure 6.9 A mycelial network in the wild. Photo: Karen Tesson

Mycelial networks develop from *spores*, which under the correct conditions germinate and begin to produce the hyphal tubules that will later become a network. A mycelial network is a *hydrostatic* network; the hyphal tubules from which it is composed are filled with protoplasmic fluid, and it is the pressure from this fluid that results in their growth. These hyphal tubules are softest and most deformable at their apical tips, so when the internal fluid pressure increases, they extend unidirectionally from these tips. The early development of a mycelial network from a fungal spore is described in more detail in Figure 6.11.

The growth of a fungal network has been described as "indeterminate" (Rayner, 1997), meaning that the boundaries of the network are *expandable*. Fungal networks are able to change and adapt according to their circumstances; they are not fixed. Mycelial networks are typically dendritic in form; that is to say they generate tree-like structures, and their branches become anastomosed at intervals to form a network.

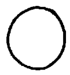
Research has shown that in many species of fungi, their mycelial branching pattern is related to their environmental conditions, and particularly by the level of nutrient resources available to them (Rayner,1997). In high nutrient domains, the branching pattern tends to be dense and frequently branched. This form of growth is assimilative, enabling maximum uptake of nutrients from the environment, and only expands slowly (Figure 6.10 a). In low nutrient domains, however, the branching pattern is quite different. Here, the branching is much less frequent, and the hyphae tend to extend rapidly as they explore the environment in a search for new resources (Figure 6.10 b). This form of branching has been called *delta-like*, as it resembles the branching patterns seen in river deltas, while the more highly branched assimilative form has been called *tributary-like* (Rayner, 1997).

Figure 6.10 a) Diagram of part of a mycelial network, where the hyphal branches are growing in an *assimilative* mode

Figure 6.10 b) Diagram of part of a mycelial network, where the hyphal branches are growing in an *exploratory* mode

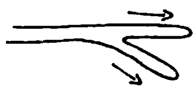
Figure 6.11 Spore germination and early development of a mycelial network.

Stage 1: Spherical Spore. Upon germination, the spore takes up water, often first expanding in all directions, before breaking symmetry.

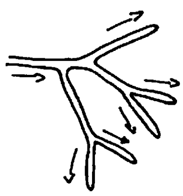


Stage 2: Symmetry-breaking of spore -development of apically extending, directional growing point (hyphal tube).

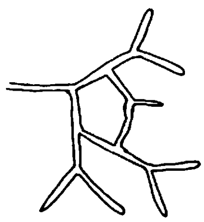
Stage 3: Growing point of hyphal tube continues to extend, eventually it splits into two or more branches.



Stage 4: The hyphal branches continue to extend, branch and develop



Stage 5: Under some conditions, the branches will anastomose (fuse), to form a *network.*



6.2.3.1 Anastomosis

The effects and implications of *anastomosis* in fungal networks have been well studied (Rayner et al, 1999). Anastomosis occurs where fungal hyphae become *fused* with one another. This process involves the breakdown of the external boundaries of the hyphal tubes, so that they may become connected to one another. The benefits to the organism are significant. On a physical level, anastomosis converts a structure where the resistances were connected in a *serial* formation, to one where the resistances are connected in *parallel*. As we have seen earlier in both the leaf venation and angiogenesis examples, this generates a number of benefits for the network. Firstly, the network now has inherent *resilience*, as it is not reliant on the integrity of a single pathway to sustain flow. Secondly, the fusing of branches creates a greater level of internal *connectivity* within the network, allowing internal resources to be redistributed. For example, if a part of a mycelial network encounters a localised nutrient source in the environment, say an uncolonized piece of fallen wood, the nutrients can be taken up in that part of the network and readily redistributed via the interconnected dendrites to other parts of the network. The overall result is that the anastomosed fungal network can be responsive to local heterogeneities in its environment, while remaining highly resilient overall. Networks that have become anastomosed in this way have been described as "self-integrated" (Rayner *et al*, 1999)

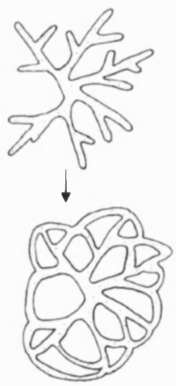


Figure 6.12 Anastomosis of branches to create a network that is *self integrated*. Diagram adapted from Rayner *et al* (1999).

6.2.3.2 Responses of communicating pathways to environmental heterogeneity

In a mycelial network, once a single branch meets with a nutrient source, the other branches that have not done the same, or that have not anastomosed with others, are functionally redundant. As the flow within the network becomes focussed on branches that have met with a nutrient source, while the branches that have not will tend to degenerate. The effect of this can be seen clearly in figure 5.14, where a few hyphal tubules from a fungal mycelium that is growing on one nutrient source, make contact with another nutrient source at some distance away.

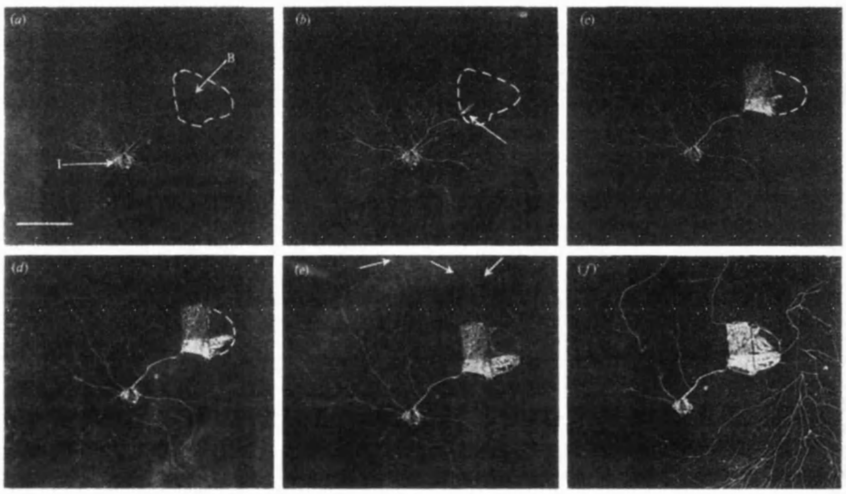


Figure 6.13 The development of a mycelial system between two nutrient sources is shown. At first a number of pathways begin reaching toward to second nutrient block. As the first mycelial links are made, the unconnected ones begin to degenerate. New pathways are laid down that integrate with and strengthen the path that had connected with the nutrient source, resulting in a strong channel between the two nutrient areas (Rayner, 1997).

This kind of growth pattern is highly efficient in a heterogeneous environment. The fungal network is focussing its assimilative structures on the areas that are nutrient-rich, while consolidating the distributive structures between the nutrient source and other key areas of the network, and minimising the energetic losses from parts of the network that are in resource-poor areas.

6.3 How natural systems manage *flow*

It is therefore evident, that there are morphological and organizational similarities across the various natural networks we have discussed. As we have seen in the examples of open and closed leaf venation patterns, and with the effect of anastomosis on drug transport within tumours, the configuration of a network's pathways can have a major effect on the flow patterns throughout the system.

Not long after Charles Darwin published his "Origin of Species", another natural scientist, D'Arcy Thompson, wrote that the "form of an object is a diagram of forces"(Thompson, 1917). Thompson suggested that the form taken by an object is a reflection of the forces, both external and internal to which is has been exposed. This is very clearly demonstrated by natural flow-form networks. The form of these natural networks is a physical manifestation of their responses to changes in their internal and external contexts. In effect, a natural flow-form network is a dynamic portrait of the constant dialogue between the system's internal and external contexts. By studying the form, development and dynamics of a natural network in relation to these contexts, we can interpret this portrait, to find a story of how the network became and is becoming the system that it is now.

As I discussed earlier, natural networks often take a dendritic form. Why is this? Is there something special about this kind of structure that makes it so ubiquitous in nature? To begin to answer these questions, I shall take my lead from D'Arcy Thompson, and look first at the forces that shape living systems, and the way in which the properties of these systems affect how they respond to these forces.

6.3.1 The properties of natural boundaries

The form of a natural system portrays the dialogue between its inner and outer contexts. This concept of inner and outer contexts is significant. In the reductionist view, a sharp dividing line is drawn between that which is *inside* and that which is *outside* of a system. In natural systems however, there is a constant and intrinsic dialogue between the organism's contents and its outer environment. The reason that this can occur is that the organism's boundaries are *differentially permeable.* They allow certain things to pass through, while others are prevented from passing.

In a healthy living system, the organism's boundaries are *dynamic*; the permeability of the boundary can vary within the organism, and this may alter from moment to moment. So for example in a fungal hyphal tubule, the tip of the tube is deformable and more permeable to certain substances than the sides of the tube, meaning that as pressure is exerted from within the network, the tubule extends from the tip, and not from the sides which are rigid and impermeable. But as the tubule grows, the regions that were once tips become sides as the fungus lays down substances that make these boundaries less permeable, meaning that the nature of the boundaries has changed. Another example is seen when part of a mycelial network enters an environment where there is little water (Rayner, 1997), and specialised boundaries are produced (known as sclerotia) that prevent the transfer of water out of the hyphae.

In a natural network, these dynamic responses of its boundaries are particularly significant, because they allow it to maintain different levels of permeability or openness to its environment in different areas of the network. For example, if one part of a fungal network encounters an area that is dry, it can seal its boundaries to prevent water loss, but at the same time another part of the network may reach a source of nutrients and respond with by making its boundaries more permeable to permit the nutrients to be taken up.

6.3.2 Boundaries create *potential difference*

The selective permeability of a natural system's boundaries means that it is able to maintain a difference between that which is *inside* and that which is *outside* of the boundaries. For example, a leaf vein can maintain a higher sugar level within the vein than that which is outside in the leaf tissue. Here, the differences between inner and outer solute levels produce a *tension* between inner and outer, reflecting the basic osmotic tendency for solutes to move from regions of high concentration to regions where their concentration is low. This tension, which is maintained and regulated by the semi-permeable boundary, is also known as a *potential difference.*

In a natural flow-form network, this boundary-mediated relationship between inner and outer creates a dynamic tension between the *entire* network and its environment, and indeed within different parts of the network itself. By creating interconnections between their branches, many natural networks are able to *influence* the potentials that exist between inner and outer contexts.

A flow-form network may also redirect flow so that it is enhanced in some areas of the network, and reduced in others. This can be controlled and affected by the production or dissipation of boundaries (both internal and external), which can bring about an alteration in the configuration of the pathways in part of the network. For example, deciduous leaves in autumn become cut off from the rest of the plant's vein network by the production of a hormone that stimulates the development of internal boundaries between leaf and stem. Another example, which I have already mentioned earlier, is during angiogenesis (the formation of new blood capillary networks). Here, in response to the release of chemicals by nearby cancerous tumour cells, an existing blood vessel will soften its external boundary, permitting new capillary branches to bud from the original vessel, which grow towards the tumour.

6.3.3 Branching and boundary sealing

At a fundamental level, like all natural systems, natural networks manage *energy*. A dendritic network structure is highly effective at assimilating, distributing and dispersing energy. As I have just discussed, in any natural system, the properties of the *boundaries* are key to the manner in which the system communicates with its environment. These selectively permeable boundaries also determine how much of the energy within the system is permitted to escape, or to enter it.

In a natural flow-form network such as a fungal mycelial network, the patterns formed by the branches are often a direct illustration of the way that the organism is managing energy flow. For example, when a fungal mycelium encounters a localised nutrient source, it produces a dense proliferation of branches. Such proliferate branching is a means of both assimilating and dissipating energy (Rayner *et al,* 1999). In this example, the fungus is producing structures that enable it to maximise its uptake of nutritional energy. Dense branching patterns are also seen in other networked systems, such as the densely branched patterns of blood vessels in capillary beds, where gaseous exchange (carbon dioxide and oxygen) occurs. Here, the proliferation of capillary tubules is acting as both a dissipative and an assimilative structure -to dissipate carbon dioxide and to assimilate oxygen.

Natural flow-form networks can also *distribute* energy. Because they are essentially communicative systems of tubules, they can transfer energy from one part of the network to another. This might be in the form of nutritional energy in a leaf venation network, variations in pressure in a mycelial network, nervous impulses in a neural network, and so on. The strengthened pathways in a fungal network between two nutrient blocks (illustrated in Figure 6.13 and discussed earlier) are acting as energy distributors. They are channelling nutritional energy that has been assimilated in the nutrient-rich area of the block, back towards the rest of the network.

Natural systems can also adapt their boundaries when energy is scarce or likely to be lost from the system, so as to retain it within. One such adaptation, is for the system to reinforce its *external* boundaries. A network example of this is seen in the honey fungus (*Armillaria mellea*). This species of fungus is commonly found on decaying tree roots, and is typified by the black "bootlace" type structures that it forms. These "bootlaces" are technically referred to as *rhizomorphs*, and are formed from aggregations of fungal hyphae arranged into cable-like structures. Rhizomorphs are able to grow extremely rapidly across nutrient-poor environments, enabling the fungal network to cross bare patches of ground to reach new nutrient-rich areas, such as a tree stump. The fungus makes the outer walls of the rhizomorphs less permeable, by coating them with a specialised water-resistant substance.

6.3.4 Anastomosis and the creation of parallel pathways.

Another way in which a natural network may become adapted to redistribute and minimise energy loss is for its branches to anastomose. Anastomosis is a key feature of flow-form networks. While many natural structures exhibit dendritic branching patterns (plant roots, for example) the existence of a dendritic branching pattern alone does not mean that a structure is a network. Structures that are *only* branched in a tree-like manner are *not* networks, as their branches are not interconnected. It is only when their branched pathways become interconnected, cross-branched, or to use the technical term *anastomosed*, that the dendritic structure becomes a *network* (Roth-Nebelsick *et al*, 2001; Ball, 1999).

Researchers have shown that the anastomosis of pathways in natural networks has a significant influence on the flow within them. For example, Roth-Nebelsick *et al* (2001) who studied leaf veins, McDougall *et al* (2002) who investigated mammalian capillary networks, and Rayner *et al* (1999), who researched fungal mycelial networks, have all recognized the organizational significance of anastomosis. In short, when pathways in a network anastomose, *parallel* connections are created. The effect of this is similar to that of creating parallel links in an electrical circuit. The anastomosing of pathways brings about a reduction in resistance in the network by allowing flow to be dispersed across more than one pathway. To borrow a term from Information Theory, anastomosis has the effect of increasing *bandwidth*.

Anastomosis also has the effect of building in a level of *redundancy* into the network, which innately increases the network's overall resilience and ability to withstand damage. Paths that are not linked with each other are highly vulnerable to damage: if there is a break at a single point, the path fails. However, paths that are cross-linked with others do not have such a high risk of failure, as the communication can simply take an alternative route.

In a fungal network, anastomosis is manifested as cross-connections between the hyphal branches. When hyphal branches become interconnected, it causes the network to become enclosed and redistributive rather than dissipative. A network that has been internally-linked in this way has been described as *self-integrated* (Rayner *et al*, 1999). As in any process of anastomosis, self-integration has the effect of reducing resistances to flow within a natural network. It allows energy to be redistributed, and minimises losses through the open ends of non-anastomosed branches. Nevertheless, while there are many benefits to self-integration processes, full self-integration is not necessarily beneficial to a network. A fully self-integrated network is completely connected internally; all of its branches are connected end-to-end, and there are no branches that point out of the network (Figure 6.12). The effect of this is that the system has isolated itself from its environment; it is protected from what is going on outside, but it also has no way of reaching out, gathering energy, or communicating with anything outside of itself. A fully self-integrated system is, to use the cybernetics term, a *closed* system.

6.3.5 The role of nodes in natural systems

A key difference between conventional constructed networks and natural flow-form networks is that the latter do not rely on *nodes* as points of interaction. In fact, true nodes are rarely, if ever found in natural networks, as their function is quite different from that in conventional networks. In a conventional nodal network, a node indicates a *transaction point*; where a link may be connect with several others, or where the communication is transformed in some way. In natural flow- form networks, however, true nodes only exist as termination points, or to quote the innovative nineteenth century biologist, D'Arcy Thompson, nodes are "points of arrest" (Thompson, 1917). Thompson described nodes in natural structures as points at which growth ceases, or is at a minimum. He also noted that when growth around such nodes begins again, it is in a symmetrical manner, extending spherically from around the node point.

Nodes of this form may be seen at the bases of many kinds of leaf, where they form structures known as *axils*, and the base of a fruits such as the cherry, or in the centre of the bean-shaped human kidney.

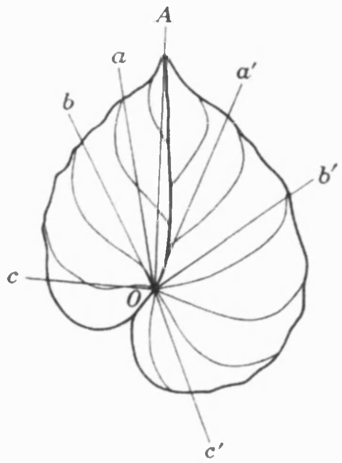


Figure 6.14 Diagram of a begonia leaf, showing leaf axil (a node) and growth around it (Thompson, 1971).

6.4 Conclusions: labyrinths and webs, strings and pipes: towards a new model of networks as *flow-forms*

As we have now seen, the structure of natural networks is quite different from that of the networks described by conventional network theory. Conventional networks are comprised of finite points, or nodes, which are connected with lines that represent transactions between them. Natural networks, however, exist as systems of permeable conduits, and are shaped by *flow*; consequently I have called these kinds of systems "flow-form networks". In short, these two models highlight the difference between a view of networks as a system of *threads*, which have been attached to one another via nodes to form a web (the conventional view), and a system of *tubes*, which become congruent (flow-form networks) to form communicative labyrinths.

In flow-form networks, communication is an intrinsic feature of the system. Unlike in the networks described by conventional network theory, communication is not a transactional process where information is passed from point to point; rather, by consequence of the tubular structure of the channels, communication in flow form networks is itself a *flow* process. The term "flow" has been used to explain other natural phenomena. Notably, Mihalyi Csikszentmihalyi (1992) used "flow" to describe a state of human consciousness, which is sometimes attained by those engaged in meditation, creative processes, certain sports, and other concentration-absorbing activities. Csikszentmihalyi explains that flow experiences reflect moments when a person has relinquished their focus on *control* of a situation, and permitted events (including their own actions) to unfold in a manner that makes them feel completely immersed in the outer world. According to Csikszentmihalyi, this kind of flow is best attained when a person turns their conscious focus away from their internal selves, and toward the outer world. At first, it would seem that Csikszentmihalyi's definition of flow, and the meaning of flow in a flow-form network are not the same. I believe, however, that they both allude to similar phenomena, which are *Inclusional* in nature. Of particular note is the way in which an understanding of conscious flow, and of flow-form networks both propose a similar conception of "self". In both these models, the "self" is seen as a contextualized being, intrinsically communicating with their environments, and with the others it encounters there.

In physical terms, in a flow-form network communication is both *cause* and *consequence* of the structure of the network; the communicative flow also has a vitalising effect on the network itself. Natural flow-form networks can respond to an imposed increase in flow by reinforcing and enlarging the pathways in use, and they respond to a lack of communicative flow by allowing pathways that are not in use to degenerate. The degeneration of pathways that are no longer in use can provide energy that is recovered and redistributed to feed the growth of the pathways that are being developed (Rayner, 1997). So, a flow-form network will open or close communication channels according to the level of flow it meets; it does this by reconfiguring its own boundaries, and in this way affects the flow within and around itself. In a flow-form network, therefore, communication, energy management and contextual relationships are all facets of the same fundamental feature of the system.

To return to a theme that I discussed in Chapter 2, the manner in which natural networks communicate relates very closely to the *Inclusional* view. One will recall that in an Inclusional view, changes in inner and outer contexts are automatically communicated by changes in the configuration of the shared medium of space, while inner and outer contexts remain distinct because they are mediated by dynamic *boundaries*. Similarly, in natural flow-form networks, patterns of communicative flow are intrinsically connected with both their inner and outer contexts, which the system can alter or affect by changing the properties and/or configuration of its boundaries.

6.4.1 Flow-form network as a mental model

Shifting between the node-focussed models of conventional network theory and the Inclusional flow-form network model requires a fundamental shift in perception. To understand the behaviour of flow-form networks we need to shift from a view of a network as a solid, impermeable and contextually disconnected structure, to one where the network is treated as a permeable and environmentally contextualized system of communicative *conduits*.

The way we think of both kinds of network has impact on the way we understand them. I would suggest that there are significant conceptual differences between conventional network thinking and an understanding of flow-form networks. In conventional networks, *content* is dislocated from *context*. The nodes are considered as entities abstracted from the environment, and existing in isolation unless connected together by links. The links themselves act as fixed connections that do not communicate with their environmental context. In all, a conventional network exists abstracted from context, and is concerned entirely with content. In such a decontextualised system, there is no way of representing, or even acknowledging the dynamic potential that exists between inner and outer environments in natural networks. Nodal networks are predetermined structures; they are constructed as diagrams of a system after it has been mapped out. As a result of its predetermined structure, a nodal system can't evolve, it can only be altered through the addition or deletion of nodes. The rigid links by which the nodes are connected do not allow the network to actively respond to its environment or to alter its channels according to flow rate.

By contrast, a flow-form network is comprised of communicative channels that are in constant dialogue with their surroundings. The boundaries of the network are permeable and flexible, resulting in an overall system that is dynamic and environmentally immersed. Unlike conventional node-focussed networks, that can only branch at their node points, the paths of a flow-form network could potentially become interconnected anywhere, resulting in flexible patterns of branching and anastomosis. The semi-permeable boundaries of flow-form networks enable environmental heterogeneity to be communicated from the outside to inside, and the non-nodal branching capabilities enable them to respond flexibly and dynamically. Flow-form networks are products of *autocatalytic flow*; they both shape, and are shaped by usage, creating novel distributive structures in response to local or global environmental changes. In flow-form systems the dimensions of the communicative channels are a direct reflection of flow rates. The dynamically responding communication links are augmented or reduced in response to use, and to changes in the environment.

To conclude, while I think that D'Arcy Thompson's quote at the beginning of this section on flow-form networks begins to suggest how we *might* think about networked systems, it needs to be revised to reflect these flow-form structures. Rather than suggesting that flow-form networks are merely *diagrams of the forces* to which they have been exposed, I argue that they are actually the *physical manifestations of the interaction between contents and contexts*. Moreover, it is my view that the novel organizational patterns demonstrated by flow-form networks can lead us to a completely new understanding of networked structures. We may gain useful insights through comparison of flow-form network structures and the conventional node-focussed networks that have been applied in many of our own organizations. I suggest therefore that, rather than relying solely on conventional network theory models when we think of "organization as network", we should consider using "organization as flow-form network" as an alternative, since this metaphor reflects the natural behaviour of communicative flow in a networked system.

In the next chapter I shall consider how one may practically apply the flow-form network model in research. My particular focus will be the methodological issues that are raised when one uses the flow-form model to interpret human social systems and organizations.

Chapter 7 – The study of flow-form networks: an introduction to the methodological issues and challenges

7.1 Introduction: the challenges of studying flow-form networks

In this chapter I shall discuss how one may investigate flow-form networks, and the methodological challenges that they present. In particular, I shall deal with the study of flow-form networks in *human social* systems. Human networks have not often been studied from this perspective in the past, although, as I have discussed in earlier chapters, they have been extensively studied from a conventional network theory perspective. Unfortunately, conventional methodologies are likely to impede or otherwise affect the understanding of a flow-form network structure. This is because they are based on conventional theories that treat networks as entities that are constructed from interrelated *components*, rather than as systems arising as a result of *flow* processes. Conventional network analysis tools are based on the premise that a network is made from separate nodes (or actors) that make connections with others through explicit action. Examples of such conventional analysis tools include those that examine the *relationships* between actors (or nodes), and tools that measure levels of *interaction* between components of a network, or that identify *transactional* exchanges between nodes.

In flow-form networks however, communication does not take the form of discrete relationships, transactions or exchanges between nodes. Rather, communication is a *flow* that may be directed, diverted, accelerated, impeded or allowed to escape. The structure of a flow-form network is created by the flow itself, which is reciprocally coupled with a flow of contextual space that recedes and re-forms itself as material substance flows outwards. So to study a flow-form network, one must study *both* the flow within, *and* the dynamic flows of the space around it. Flow-form networks might be created by fluids, collective actions or movements of particles or actors (such as ants, people, cars in traffic etc.), or by thoughts, language and so on. Reciprocal flows of space that recede around a network as it develops are perhaps not so easy to identify, but they might be manifested in *contextual* changes.

7.2 Investigative tools that do not disrupt flow in networks

Unfortunately, investigative tools that treat networks as naturally evolved fluid systems are scarce, and there are not many prior examples of network studies that consider communicative flow as a continuous and non-transactional process. The only tool that I have encountered that deals with a network in a manner that does not disrupt its flow-form nature is a *fractal* measurement. The term "fractal" was coined by Benoit Mandelbrot (1983) and is a concept related to complexity theory. A fractal structure is one that looks similar at different scales of magnification. One example of a fractal structure is the British coastline. Regardless of whether it is viewed at a distance (say from an aeroplane), or closer when we walk alongside it, or closer still when we examine the shape of the rocks under our fingertips, at all these scales the coastline has a similarly jagged and irregular outline. Dendritic Networks may also be fractal, appearing to have similar forms whether they are viewed from a great distance, or greatly magnified. As well as introducing the concept of a fractal structure, Mandelbrot developed a way of measuring how "fractal" a structure is, which was effectively a measurement of the range of scales at which the structure looks similar. This measurement is known as the "fractal dimension". One interesting feature of the fractal dimension is that it may also be considered to be a measure of how "space filling" a structure is. A network that has a large fractal dimension has many levels of branching, and therefore one may magnify it greatly and it will still look to have a similar branching pattern. The branching pattern of a network with a small fractal dimension is less dense, so one couldn't magnify it much before the branching pattern disappeared. Effectively then, the fractal dimension of a network is a measure of its branching density, or of the space-filling quality of the network.

Several researchers have used fractal dimensions to investigate dendritic networks. For example, Family, Masters and Platt (1989) developed a method for measuring the fractal dimension of the network of microscopic blood vessels in the human retina, indicating the density of the network; while Boddy *et al* (1999), measured the fractal dimensions of various fungal mycelial networks and demonstrated that a fractal measurement was one way of identifying differences in network branching quality. Pelletier and Turcotte (2000) conducted a similar study, where they calculated the fractal dimension of leaf venation networks and compared them with those of river networks.

So, calculating a fractal dimension is one way of measuring networks that have dendritic structures, and of making comparisons between different types of networks that have apparently similar structures. This technique however relies on being able to *see* the structure and branching patterns of the network, as is possible in blood vessel networks, or river flow networks. In many human social networks, the network structure is not physically apparent, but *implicit*. I shall return later to the problems of making implicit social network structures explicitly visible. Suffice it to say here, that it is quite possible that the implicit, or hidden nature of flows within human social networks is one of the main reasons why human networks have not been studied using methods that reveal communicative flow. It is much easier to observe and quantify communicative *transactions* within a network, such as incidences of interaction between people, or of exchange of documents and so on. The problem is that the application of such transactional analysis in isolation, can *only* lead to a transaction-based understanding of network structure. The problem is exacerbated because transactional-based research methodologies endorse the conventional network theories that are currently so much in vogue, and hence have become hugely popular.

Nevertheless, it *is* possible to study flow-form networks by using transactional tools, despite the fact that it is not really what they were designed for. To be useful in the study of flow form networks however, these transactional tools must applied with an understanding of how a flow-form network may respond to such analysis, and ideally in conjunction with other kinds of tool. Transactional analysis *alone* will never reveal the true nature of any underlying flow-form network in a system.

7.3 The risks in unknowingly applying conventional tools to flow-form networks

The example that follows illustrates how using a conventional transaction-based methodology to study a flow-form network, *without awareness* that this is what one is doing can result in a grossly incorrect understanding of its structure. The example concerns the creation of a map of the Internet.

The Internet is often viewed as a system created entirely through human design. Huge amounts of resources are invested in the design of formally structured networks and in integrating them with the rest of the 'net. The routing systems that handle and direct the traffic that flows on the Internet are subject to well-established protocols and are designed according to predictions of use and required capacity. Structurally, the Internet could be viewed as analogous to a human highway system (Gabor & Csabai, 2002). In terms of hardware and bandwidth, it is certainly the product of considerable human design effort. However, the growth of the Internet, the ways that it is used, and the patterns that these have generated are often less formally structured. Some have suggested that in overall system terms, the Internet is more akin to a living system (Chen, 1997; Heylighen and Bollen, 1996).

7.3.1 An example: Lumeta's Internet map

Since the days of its inception people have created "maps" of the Internet. These maps have taken many different forms, and illustrate many different aspects of the net, from its topology, to its content, and its users. Figure 7.1 shows a map of the Internet created by Burch and Cheswick at an organization called Lumeta in 1997. This particular image was published in "Wired" magazine in 1998.

The map created by Lumeta shows the extent of the *connections* within the Internet. It was constructed through use of a network diagnostic tool called traceroute. Traceroute is a simple network command that shows the *route* that a "packet" of data takes through the Internet. A traceroute query is issued from a known start point to a defined end point, the object being to show the route that the query has taken from point to point, and how long it took to reach each stage. A typical response to a traceroute enquiry appears in Table 7.1.

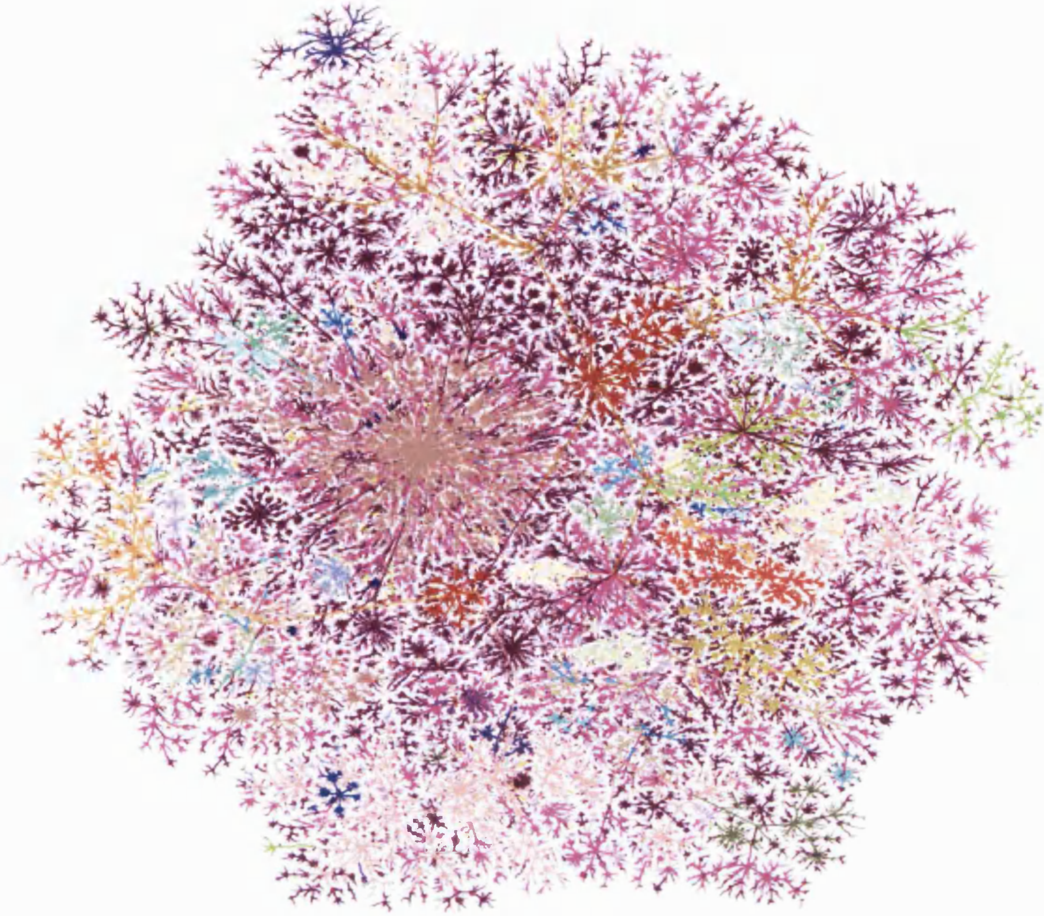


Figure 7.1 A map of the Internet created by Burch and Cheswick , Lumeta Corp., 1997.

To produce the visual map of the Internet, the Lumeta research group conducted thousands of traceroute enquiries. The addresses of the servers for the traceroute enquiries were gathered from the data tables of registered servers that are held on routers (traffic managing nodes) on the Internet. The results of these enquiries were then collated and transformed using a computer "spatialization" program to produce the visual map. Although the algorithm used to produce the spatial map is relatively simple, the enormous number of nodes that have to be arranged means that the production of each map takes several hours on a normal PC.

Tracing route to
pingu.bath.ac.uk
[138.38.32.5]over a
maximum of 30 hops:

1	16 ms	<10 ms	<10 ms	ata-bsl.router.bourne-steel.co.uk [62.49.84.105]
2	31 ms	31 ms	32 ms	bsl-ata.router.bourne-steel.co.uk [62.49.84.100]
3	31 ms	32 ms	31 ms	poole-adsl.router.bourne-steel.co.uk [62.49.84.97]
4	188 ms	62 ms	63 ms	thus1-hg3.ilford.broadband.bt.net [217.32.64.74]
5	47 ms	47 ms	63 ms	217.32.64.1
6	187 ms	78 ms	94 ms	217.32.64.106
7	47 ms	47 ms	63 ms	anchor-border-1-4-0-2-191.router.demon.net [212.240.162.126]
8	63 ms	47 ms	46 ms	tele-border-1-4-0-2-234.router.demon.net [195.173.72.49]
9	47 ms	63 ms	47 ms	linx-gw2.ja.net [195.66.226.15]
10	62 ms	47 ms	63 ms	gi4-0.lond-scr3.ja.net [146.97.35.129]
11	63 ms	46 ms	63 ms	po6-0.read-scr.ja.net [146.97.33.13]
12	63 ms	62 ms	47 ms	po2-0.bris-scr.ja.net [146.97.33.49]
13	141 ms	47 ms	109 ms	po3-0.bristol-bar.ja.net [146.97.35.150]
14	172 ms	62 ms	78 ms	brisc-2.swern.net.uk [146.97.40.102]
15	47 ms	62 ms	63 ms	bath-1-brisc-2-r2.swern.net.uk [194.82.125.158]
16	63 ms	62 ms	94 ms	bath-gw-1.swern.net.uk [194.82.125.198]
17	*	*	*	Request timed out.
18	63 ms	62 ms	63 ms	pingu.bath.ac.uk [138.38.32.5]

Trace complete.

Table 7.1 Typical response to a traceroute query.

7.3.2 The Internet map's inherent problems

Visually, the Lumeta map is striking. At first sight it appears structurally similar to some of the natural flow-form networks that I have discussed, as it has dendritically branching pathways, radiating from a source somewhere towards the centre of the map. Superficially, it looks similar to a fungal network, or perhaps to a blood capillary network.

On closer inspection however, it becomes evident that this map of the Internet has no cross-links between the branches; it lacks the anastomoses found in a healthy natural flow-form network. This kind of structure, without cross-linking branches, *is* found in the natural world, but in natural flow-form networks, it is a sign that the system is *dysfunctional*. An image of a dysfunctional fungal mycelial network is shown below (Figure 7.2). This mycelium is the dysfunctional offspring of a cross that was made between American and USSR strains of the same fungal species. Unlike a healthy fungal network, this unhealthy example has switched to a form of growth that lacks cross-links between its branches. As I explained in the previous chapter, in flow-form networks, anastomoses play a vital role in establishing resilience and fault-tolerance in a network. A fungal network that lacks anastomotic branches will be unable to communicate effectively within the system.

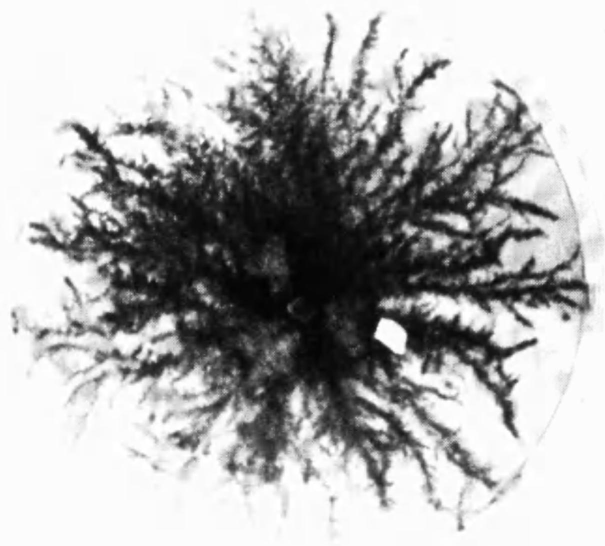


Figure 7.2 An unhealthy mycelial network. This mycelium is the offspring of a cross that was made between American and USSR strains of the same fungal species (Ainsworth *et al*, 1992).

So we have a paradox: the Lumeta map of the Internet that makes it look like a dysfunctional flow-form network. Yet it is well known that the Internet is a dynamic and thriving network, possibly even more so when this map was created in 1998 when the "dot com" boom was at its height. The Internet also exhibits, at least to an extent, a level of fault tolerance. If we try to access a U.S web site from the U.K., it usually doesn't matter if some of the lines between are down, as the traffic simply takes an alternative route.

The solution to this paradox lies in the nature of the tool that was used to create the Internet map. Traceroute is a discrete point-to-point tool. A traceroute query is issued from a known start point, to a defined endpoint. It indicates that a server exists at that endpoint, and shows the route that is taken to get there. So the image, created through use of traceroute, merely shows the server *connectivity* that existed within the Internet at a fixed point in time. Each branch on this network was created through a separate query from a fixed start point. So even if cross-branches do exist, between the connecting branches, this tool wouldn't find them. Furthermore, the tool provides no indication of the carrying *capacity* (bandwidth) of the Internet. It doesn't show which paths are used more, or which carry less data. It merely shows where there is a proliferation of branches, due to the presence of an abundance of servers at a particular location.

So two significant points emerge from consideration of this image. Firstly, the Lumeta map actually doesn't show a full picture of "what the Internet is like". The representation of the Internet in this map shows a small facet of how the Internet is organized, and it offers one *perspective* on this organization. Secondly, the reason that the Lumeta map provides this unilateral perspective is that this is what the enquiry tool used to create it was designed to do. There is no way that using the traceroute tool *alone* would result in anything other than a one-sided, target-based map of the Internet, that was unrepresentative of the whole system. This example therefore demonstrates to us the inability of inappropriate tools of enquiry to detect inherent connectedness, and highlights the need for appropriate tools and methodologies.

7.4 How conventional tools may be used to study flow-form networks

Given that the number of investigative tools that do not disrupt the flow in flow-form networks is limited, often the only network measurement tools available are those based on non-fluid models. Finding new tools to study natural networks is potentially a mammoth task, and was beyond the scope of this research study. Yet, although the lack of ideal tools presents a problem, we are not entirely prevented from studying flow-form networks in a manner appropriate to their form. I believe that we can use conventional tools, provided we remain aware of what we are looking at with them. To use an analogy: simply studying the properties of a cup of water will not tell us the properties of a river. If however we *compare* the behaviour of the water in the cup with that of the water in the river, we may learn much.

The focus of my own research was how the natural network metaphor might be studied in a human social context. So one of the principle challenges that I faced was finding how to use existing analytical tools to investigate flow-form networks in a human social context.

7.4.1 Multiple methods in one study

One way of tackling the problem is to use a multi-method approach. Using several contrasting methods for enquiring about a system could perhaps "fill in the gaps" that would be left if one were to use a single method on its own. Multiple method studies have been used often in the social sciences, where the approach is referred to as *triangulation*.

Ackroyd and Hughes (1992) explain that in the social sciences, triangulation provides a more complete picture of the system. They suggest that using several different methodologies in one study can encourage systematic continuity in the data, and overcome bias in the different data forms. They do point out however, that there are disadvantages to using several methods in a single study. One of these is the cost, the other is a theoretical issue: In the social sciences methods for collecting and analysing data are usually based on particular theories or models. Often as a result of this, a particular method cannot be combined with other methods that are based on different models. An example is discourse analysis, which asserts that every incidence of analysable discourse is but one "version" of an event; these versions stand as independent analysable accounts, but cannot be correlated with each other, or with any other form of data. So for example, a discourse study of a newspaper report could not be *correlated* with an eyewitness account, even if they are both about the same event, because discourse analysis treats each as an *independent* version. According to Silverman (2000), who also wrote about this problem, using data from multiple sources will not necessarily provide a more complete picture; it depends on whether the data can be related to each other, they may be making different assumptions about the world, and so cannot be correlated with each other.

According to Gomm (2004), triangulation has been used in the past to crosscheck different sources. For example, diaries or news reports may be compared with official records. In this case, the triangulation is done to check the *validity* of the data, not to get a clearer picture of a system. Ackroyd and Hughes (1992) suggest however, that in recent years, this approach has been largely rejected; the trend is now towards greater flexibility in methodological design and an emphasis on building up a picture from diverse sources.

7.5 Methods for study of human social networks

A principle concern in studying flow-form networks in human social systems is how one may go about finding what the flows *are*. What are the communicative media, and what is it that the flows are composed of? Potentially, the "fluid" (or flow medium) could be any number of things, both tangible and intangible, and both implicit and explicit. Flow may be represented by the collective movements of people (such as highway or footpath traffic), the spoken word (radio, face to face conversation, telephone conversation), the written word (letters, text messages, emails, internet chat), or intangible "qualities" such as trust, friendship, loyalty or respect. The potentials are virtually limitless.

A second problem is how one might *represent* these flows, visually or otherwise, to expose or reveal the network flows of the system. One would imagine that flow patterns in human social networks might be exposed by investigation of collective movements of people. Potentially one could construct maps of footprints, paths of people recorded by video tracking, or by using electronic tags to track the collective movements of people. However, although I have encountered research that uses electronic tags, video tracking and so on to monitor interactions between individuals (McCarthy and Meidel, 1999; McCarthy *et al*, 2001; Borovoy *et al*, 1997; Borovoy *et al*, 1996), I have not found any examples of researchers who have used them to study human communication as a network formed by *flow*, i.e. they have all focussed on *transactional exchanges* between individuals, rather than on communicative flow. This could be because, as I found in my own research, the development of tools that track *people* can be both costly and difficult, and is still in its infancy. It is also likely however to be a reflection of the popularity of conventional network theory, which has resulted in a focus on conventional methods that view *transactions* within a network as key to network structure, rather than communicative flow.

As I have already mentioned in an earlier chapter, social scientists were among the first to work on what has become conventional network theory, and in recent years a wide variety of human "networks" have been investigated. For example, Karathanos (1994) investigated the networks that are created through formation of coalitions and partnerships between people in organizations, while De Laat (2002) made a study of the networks created through the online discourse of the members of a Dutch police organization, focussing on how networks created online affected the sharing and construction of knowledge. Loosemore (1998) has looked at the influence of networks during crises in construction projects, while Cheng *et al* (2001) have made a more general study of the influence of communication networks in the construction industry.

7.5.1 Social network analysis

One of the most popular techniques used to analyse networks in human social systems is a method known as "social network analysis". Social network analysis is a technique for studying social interactions. It identifies and describes networks of people and/or other "actors" in a system and their relationships to each other. Social network analysis (hereafter referred to as SNA) has been applied in a wide variety of human social contexts, including analysis of family ties (Bien *et al*, 2001), studies of juvenile gangs (Baron and Tindall, 1993) and problem-solving networks in organizations (Stevenson, 1993). Social network analysis techniques have also been used to analyse computer networks (Ramaswamy, 2001), ecological relationships (Faust and Skvoretz, 2002; Corner *et* al, 2003), and even for conversation syntax analysis, where researchers were looking for how words were related to each other in texts (Brandes and Carman, 2003; Dooley *et al*, 2003). It has also been used extensively to analyse email and other online communication, in fact currently it seems to be used more for that than anything else (Reffay and Chanier, 2002;

Paolillo, 1999; Arenas *et* al, 2003; Huberman and Adamic, 2003; de Laat, 2002; Papakyriasis and Boudourides, 2001).

The principles of SNA are simple; one identifies a set of nodes or "actors", and then the relationships between them. So for example if one were looking at newspaper purchasing patterns, one could identify the people involved in buying newspapers, and then link the nodes according to the relationship "buys newspapers from".

In social network analysis, there are two generally accepted ways to display the data, as a *matrix*, or as a *graph*. A matrix charts the relationships in a tabular format. In the table below, "buys newspapers from" is identified by a 1, and "does not buy newspapers from" is identified by a 0.

	Ted	Joe	Bill
Ted	*	0	0
Joe	1	*	0
Bill	1	0	*

Table 7.2 Network matrix showing newspaper-purchasing relationships

In a graph format, the network actors are represented as diagrammatic nodes, and the relationships between them as lines connecting the nodes, as in the figure below:

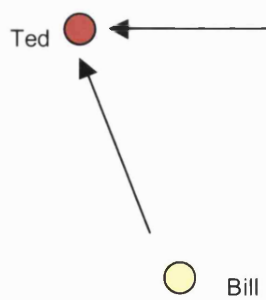


Figure 7.3 Network graph showing newspaper-purchasing relationships

For a simple network, such as this one that only has three actors, a matrix is easy to interpret. Indeed to conduct a full social network analysis, it is not necessary to plot the network in a graphical format. Should the network be much larger than the example here, however, a graphical format can make it easier to identify and visualise the relationships that exist.

Note that in the network in Figure 7.3, the lines connecting the actors have arrows. These represent the *directionality* of the relationships. In the example above, this indicates that Bill buys papers from Ted, but Ted does not buy papers from Bill; the link between them is *directed.* If Ted did also buy papers from Bill, the link between them would have arrows at both ends to indicate this, and the link would be described as *reciprocal.* These attributes are important in network analysis because they can affect the way that the data are subsequently analysed.

It is possible to make separate analyses for the various factors of influence in a social network. For example, one could construct one network that shows who the actors turn to for *advice*, and another that shows who they *trust.* These networks may have quite different structures, and hence might reveal an interesting facet of the social system.

7.5.1.1 Analysis of data in social networks

There is a whole set of specialized statistical analysis tools that can be applied to social networks. These tools can be applied to individual nodes, or to the whole network. For example, one measure that can be applied to the entire network is of its "density". This is a ratio of the number of *actual* links to the number of *possible* links in a network; it shows how densely interconnected a network is. Another such measure identifies "cliques" or clusters within the network, to give an indication of how coherent the network is, and whether it is subdivided into intercommunicating subgroups.

There are also a number of measures that can be applied to individual nodes in a network, giving an indication of the variations in roles that exist. These include "centrality", which is a measure of how well connected a node is to the network. Another is known as "betweenness", which is a representation of the extent to which a node acts as a "liaison" or connector between other nodes. There are many others in addition to these.

There are a number of computer programs that will analyse network data, including one titled UCINET (Borgatti *et al*, 2002), which has been specifically written for the task. There are also several software packages that will transform network data matrices into a graphical or visual format (Borgatti, 2002).

7.5.2 Using other methods in conjunction with SNA

The primary disadvantage of SNA is that it is based upon a notion that networks are *constructed* entities, composed of nodes interconnected by links that represent relationships or transactions between them. Social network analysis focuses on the transaction *points* within a network; it is a node-centred analysis. The relationships between these transactional points are analysed independently of their contexts, and indeed often independently from the *content* of the communication. Social network analysis emphasises the *structure* of a social network, without necessarily referring to *what* is being communicated within it, or why it is being communicated at all.

I would suggest that on their own, the results of SNA are of limited value. A network that is analysed in terms of structure alone will only confirm whether a network exists, and if so what form it takes. A structural analysis conducted in the absence of content studies and appreciation of context, will not provide answers to any of the "why" questions, or explain *how* the network came to be organized in that way.

7.5.2.1 Content analysis

A number of previously published studies have overcome this to a degree, through a dual approach to data collection on social networks, collecting both interaction data for SNA, and conducting content analysis of *what* was communicated (De Laat, 2002; Paolillo, 1999; Loosemore, 1998; Aviv *et al*, 2003).

De Laat's (2002) study concerned the network organization and discourse content of an online community. The community in question was a Dutch police organization, and the online vehicle was a pre-existing computer-supported collaborative learning (CSCL) environment that supported information exchange and work-related discussion. The data collected by De Laat consisted of log-files of online dialogue from the CSCL system. He used the interaction data gleaned from these to conduct a social network analysis, producing measures of centrality and betweenness. The UCINET software package was used to carry out the social network analysis. For the content analysis De Laat used a pre-existing quantitative coding scheme to code and analyse the discourse.

Aviv *et al* (2003) conducted a similar study. They also looked at transcripts from CSCL communities, this time the communities concerned were groups of students taking an Open University course. The methods here included various SNA techniques, using a commercially available network analysis software package to conduct the analysis. In addition to this, the transcripts were analysed for content, and like De Laat's study, employed a pre-existing coding scheme. The authors of this study were particularly interested in how actors form groups within networks, and used the SNA to identify "cliques" and "cohesion" within the network.

A study using similar methodological principles was conducted by Paolillo (1999). This study concerned the social network and language use of the participants of an IRC (Internet Relay Chat) community. Here, similarly to De Laat, the data consisted of log files containing the online conversations. These were used to glean both interaction details for SNA, and for content analysis. Paolillo devised his own coding scheme for the content analysis, which categorised statements according to whether they contained one of five linguistic features. The content analysis was summarised quantitatively, and correlated with the quantitative results of the social network analysis.

Finally, Loosemore's (1998) study focussed on the interactions of participants in a construction project when a crisis was encountered. He collected data in the form of letters, faxes, audio records of telephone conversations, notes from meetings and semi-structured interviews. With these he conducted both a qualitative content analysis of the communication, and a social network analysis of the interactions that occurred. Initially, the content analysis results were used to categorise the interaction data into three "phases", to produce three interaction matrices for SNA. The matrices were analysed using UCINET to produce a series of SNA outputs on features such as centrality and betweenness.

Like myself, Loosemore points out that a major limitation of SNA is that it does not show details of the information that was communicated. For example, in the final phase of the construction project, the SNA showed quite positive results, in terms of high levels of communication. Loosemore's content analysis however, indicated that the communication actually concerned the increase in problems arising on the project, and that the nature of the communication was becoming progressively more acrimonious. By using qualitative content analysis in association with the quantitative SNA, Loosemore identified the details of the communication content, and was thus adding depth to his results. To paraphrase his comments, the content analysis enabled him to answer some of the "why" questions about the SNA results.

7.5.2.2 Analysing use of artefacts

Some have further expanded on the benefits of a dual method approach, by using multiple methods to study networks. Sonnenwald (1996) took such a multi-method approach. She collected many different forms of data, from several different companies (all involved with design), over a considerable period of time. The data types included structured and unstructured interviews, documents, meeting notes, network interaction data, telephone transcripts, and other documentation. The interaction data were used to conduct an SNA, while content analysis techniques were employed on the other forms of data. Amongst these techniques were methods referred to by Sonnenwald as Event Sequence Analysis, and Concept or Thematic Analysis.

According to Sonnenwald, the benefits of this kind of study technique included the following:

- It allowed the designers' own perceptions and reflections and shared experiences to come to light
- It made use of many forms of data, so that more data could be collected
- Using data from different settings (companies) allowed patterns that might be more general than for one specific company to be shown

The method used by Sonnenwald to integrate all the different forms of data was qualitative, and unlike some of the dual method studies, she didn't quantitatively cross-analyse the content and structure studies.

Other authors who have chosen to use multi-method approach to studying communicative networks haven't specifically used SNA, rather they are using methods that are *like* SNA. For example, Perry and Sanderson (1998) studied coordination and dialogue within two collocated design teams. One was a team of engineers designing a pump, and the other a team of construction designers (architects, engineers etc.) designing an office block. The authors were particularly interested in how "artefacts" were used to coordinate the design work. Artefacts are documents, faxes, drawings, sketches etc., anything that represents and communicates the ideas of the designers. To collect data on the use of artefacts authors conducted interviews, observed meetings, observed the teams at work, and examined archived documents and artefacts produced by the designers. The analysis was qualitative, and the results discursive. They highlight the importance of artefacts as communicative tools, and the significance of collocation both as a means of sharing artefacts easily, and of facilitating team meetings.

In their paper, Perry and Sanderson highlight the joint significance of artefacts and social interaction, as well as the role that co-location plays in facilitating the use of both. They do not discuss the methodology they used, that is to say they do not mention any benefits or challenges to the way they collected their data. They do say that the two studies of the design teams were conducted by different people, and then the results compared for the paper. They suggest that this may help to identify patterns across organizations, and may encourage researchers to reflect on the differences they encounter.

Medway and Clark (2003) studied the design processes within two Canadian firms of architects. Their data collection methods included extensive field notes of observations, audio tape recordings, records of spontaneous explanations etc. offered by participants and copies of documents referred to or generated by the participants. As an initial means of investigating and coordinating the data, the authors produced "maps" of the "design streams". Represented on these conceptual maps were participants, artefacts, conversations, meetings and so on. These were not strictly SNA maps, but they do show the flow of information and communication between participants, and over time. The authors made an extensive and qualitative content study of the spoken interactions that were recorded. In comment, they say that they like the maps they produced, as they "indicate the movement of ideas"... and they "provoke speculation and imagination".

Ruhleder (1997) describes a video-based interaction analysis that she used to analyse communication within an organization. This analytic technique combined videotaping of interactions between people in an organization with participant observation, interviews and analysis of documents and technologies. The object was to analyse how people interact with one another, and with their physical environments, documents, artefacts and technologies. The videotapes were used as the basis of the analysis. The tapes were first logged for content, where a summary listing of the events on the tapes was created. Subsequently, interesting sections of the taped content were transcribed. Teams of researchers worked together to code the content of the transcriptions. They did not use a predetermined coding scheme; rather coding categories for the data were allowed to emerge from deep consideration of the data. As the video data are progressively analysed, the patterns that were found were cross-checked with the other forms of data that were collected, which included documents, field notes, interview transcripts, and so on.

7.6 A combined methodological approach to studying human social networks

These examples have indicated how some other researchers have used social network analysis to reveal structural aspects of human networks, while overcoming some of its shortcomings. The critical factor in conducting research of any kind, but particularly in the study of flow-form networks is to remember exactly what the methods we employ are actually telling us. SNA will give us an idea of the *transactional* relationships within a network, but it won't tell us *why* these relationships occur, or how they are related to the context of the system. It can however relate how people move within a system, and indicate whether they communicate with many others, or are non-communicative. It can also highlight incidences where people share contexts, such as in meetings. SNA might show that there was a gathering of people, and by combining this with contextual or content data, one could get an idea of *how* they were sharing contexts.

Meanwhile, content analysis (such as analysis of interviews, recorded dialogue etc.) will give an idea of *what* is communicated. Through content analysis, we can create *snapshots* of content, captured at a particular instance in time, and convey a static picture of what was communicated at that point.

Content analysis alone will not however show how the dialogue relates to the wider context of the system. This is where artefact analysis is appropriate. Analysis of how artefacts are used (to include computer documents, design sketches etc.) will show how people communicate the concepts in their minds to others in a tangible way, producing items that can be kept, referred to later and used as records. Analysis of the content of these artefacts will mean little without reference to the dialogue that surrounded them, or the contexts in which they were produced. Yet when data from artefact analysis are combined with SNA, they can indicate how people are communicating when they are not using dialogue, or how the artefacts *augment* the dialogue. Significantly, artefacts can represent *flow* of information within a system, a document may be passed from one person to another, two people may work collaboratively on a document, or a sketch may be used to convey the ideas of many people during a design meeting. The way that people use artefacts may bring meaning to some of the less clear relationships that emerge from SNA.

In all, while these analytical methodologies will never generate an entirely life-like model of the structure of a human flow-form network, the use of *multiple* analytical methodologies can provide a picture that is more comprehensive than analysis that relies on a single conventional method alone. Using several methods together, one can gain insights into a system from different perspectives, creating *snapshots* that can be combined, hologram-like to produce a multi-faceted picture of the entire system. By remaining aware of exactly *what* one is doing with a particular method, one can mitigate against the limitations of one method, by augmenting it with another. The challenge is to deduce from the alternative views of a network, SNA, content, artefact use etc., how they may reflect the *flows* within. By looking for correlations between the data, one can hope to find similar flow patterns. If the data correlate, one may have identified a pattern within a part of the network. If the data do not correlate with each other, perhaps there isn't flow, or perhaps it has been impeded. Alternatively, the lack of correlation between the different data sets might not indicate that there is no flow; it might exist, and the methods simply haven't detected it. The challenge then is to work out whether the lack of correlation results from a problem in the network, or from a problem with the methods.

Chapter 8 – Teamwork study: aims, context and rationale

8.1 Introduction – aims of the study

This chapter introduces an investigative study that I conducted as part of my doctoral research. The overall aim of this study was to investigate whether, and if so how, communicative networks emerge and develop within a human business context. In this chapter I shall outline the aims and rationale of the study, and introduce some of the pre-existing issues and business contexts that formed its background.

Although this empirical research appears towards the end of my thesis, this actually does not reflect the chronological sequence of events in my research process. I conducted the study in 2001, but the bulk of the *theoretical* work took place after this. The empirical data, and research experience, therefore acted as catalysts for my subsequent theory development, and it was through consideration of the empirical data that I developed the flow-form network model of communication. This practical study therefore serves in this thesis as a set of findings, which can be used to *exemplify* the power of the flow-form network metaphor, rather than as a formal test of the theory.

Business networks have been studied extensively by other researchers. For example, Cheng *et al* (2001) studied the influence of communicative networks within the construction industry, Olkkonen *et al* (2000) made a more general study of communication networks in business relationships, Karathanos (1994) made a study of the state of communication networks when coalitions between organizations break down or become dysfunctional, Ruef (2002) studied how strong and weak ties within business networks can influence innovation, and Stevenson (1993) investigated the nature of problem-solving networks in organizations.

These past studies have, however, all been conducted from a conventional network theory perspective. For the most part, past research on human networks has focussed on network *transactions*, and on networks of *relationships* between people and other entities, rather than on patterns of communicative flow. In this practical part of my research study, in contrast to the transaction-focussed studies of others, I wanted to investigate the communicative *flows* that emerge as people work together. My intention was to study this on both a macro and a micro level, looking at medium-scale patterns of human interaction, as well as conducting a more detailed analysis of communicative processes. Through this study, I hoped to reveal some of the ways that flow might be encouraged and/or hindered as people work together.

When a flow-form network develops, it is intrinsically connected with its environment - to the extent that a very close relationship between a communicative network and its environment might even be seen as a diagnostic feature of a flow-form network. So, in recognition of this, it was important that a part of my investigation considered how the people engaged with their environment and with the artefacts around them. Questions that needed to be considered included: were artefacts used at all as communicative tools? Did the surroundings of the people affect how they communicated, and if so, how?

As well as looking for communicative network patterns within the system, I was also interested in how the enquiry tools I chose to use might have affected my results. As I discussed in the previous chapter, the methods available for the study of human social systems are not inherently suited to finding flow-form networks. But since they are the only methods available, in this study it was important to choose and use the data-collection and analysis methods carefully, with an awareness of how their application might have affected the picture that emerged.

8.2 The context of the study: Teamwork

Before the start of my research, I already had a connection with a number of different companies who were potential candidates for such a study. The company I finally chose was a steelwork fabricator, of medium size (100 + employees), based in Poole in Dorset. Through working with this company an opportunity arose to study their involvement in a DTI funded construction industry project called "Teamwork".

Teamwork, based in London, had been running for three years, culminating each year in a week-long "Liveweek", where teams of people from different companies were brought together to work collaboratively on construction designs while co-located in a single large hall (Florence Hall at the RIBA). The exact set-up each year was slightly different. In 2002 (the year when my study took place) a number of informal design teams were each given the task of designing "virtually" a complete computer model of a large building, having regard to all aspects of design, fabrication, erection and use. By the end of the week, the building was to be ready for construction. The Liveweek environment was experimental, and all the buildings were simulated projects, so there was no real building at the end, although there could have been.

8.2.1 Background to the study context – the British construction industry

The Teamwork event lay within the broader context of the British Construction Industry. To explain the basis of Teamwork, which was a new and different mode of working, it is necessary first to describe some of the issues faced by the construction industry in general.

It is recognised within the British construction industry that there are huge problems of communication in major projects, where large numbers of people with different experience and loyalties have to come together for a short time to produce a single unique outcome, a building. This building will then have another diverse set of people who will use it over a long period of time. Large projects, of the sort tackled by Teamwork might involve several thousand people, to include architects, cost estimators, steelwork engineers, heating engineers, site workers, electricians, telephone engineers and so on. A great variety of different components of a building, from structural steel, glasswork, heating systems and so on, all have to be dealt with in an integrated fashion. Aspects such as strength, functionality, aesthetics, safety, as well as its environmental and social impact need to be considered, to name but a few. Such complex projects inevitably incur misunderstandings and errors and a subsequent correction process.

So, the design of a large building, such as an office block, or a theatre requires the coordination of people with many different specialist skills. The various specialists within the industry have been using complex computer models for a long time. Until now, it has not been easy to exchange data between say, the architect's model, the engineer's model and the services model and so on. Solving this interoperability problem has been seen by many as a solution to the industry's communication problems (Auoad *et al*, 1999; Marsh & Flanagan, 2000). Others maintain that improving the technology itself doesn't resolve communication issues, it's more a question of how it's used (Cheng *et al*, 2001).

Studies have already been conducted on communication in the construction industry. Notable examples include Cheng *et al* (2001), who investigated the forms of communication networks that exist within and between construction engineering companies, Sonnenwald (1996) whose study on communication during the construction design process was mentioned in the previous chapter, and Loosemore's (1998) study on communication in construction teams during a project crisis, also mentioned in Chapter 7.

Another topic that is highlighted within the construction industry is how multi-skilled design teams work together, and how the collaborative *design* process is undertaken. For example, Perry and Sanderson (1998) studied the use of artefacts such as drawings and other documents as communicative tools during the design process, while Medway and Clark (2003) have taken a more cognitive approach, looking to identify the thought and language processes that are involved in collaborative construction design.

Teamwork studies have also been conducted within the construction industry context. Austin & Steele (2001) studied how teams work together during the early conceptual design phases in construction, while Sonnenwald's (1996) research on communication roles in design teams includes a study of an architectural design situation. The pervading theme throughout all of these studies is that, in construction the integration of elements such as coordination of design and management tasks, team communication, and communication between people with different skills, is a highly complex issue.

8.2.2 The Teamwork tasks in detail: how Teamwork differed from the conventional approach

The ultimate object for each team at Teamwork's 2002 Liveweek was to design a building. The team members were to create their design collaboratively, dealing with as many detailed aspects as possible; this included architecture, structural engineering, services engineering, quality and cost issues, design of internal fittings etc., as well as design issues relating to erection and fabrication of the building.

The design was to be presented in the form of one or more CAD (computer aided design) models, to as detailed a level as possible. In practical terms this meant designing and integrating a great many component structures, including steelwork, cladding, heating/ventilation pipe systems. Many of these structures require specialist skills in their design, so the project involved collaboration between a number of people with different specialist skills.

At first it might seem that this isn't very different to the tasks and problems that are faced by construction projects in the "real world". However, the difference in the Teamwork approach was that the entire design had to be completed fully collaboratively, with the bulk of the design work being completed in just two days. In normal real life projects this process takes much longer, often weeks or even months. It is not uncommon for designs to be delayed by problems in integrating the different structures. For example, the structural engineers may produce a framework for the building that is later found to conflict in certain areas with the ductwork system designed by the services engineers. One of the risks in real life projects is that these problems might not be spotted until construction on the building has begun, at which point they may be costly and difficult to resolve.

The principle object at Teamwork therefore, was to resolve conflicts and design problems by bringing together and collocating the entire design teams at an early stage in the project to work in an integrated and cooperative fashion. By doing this it was hoped that potential problems could be addressed and ironed out earlier. It was also hoped that the closer working relationships would encourage innovation of novel design solutions.

One of the key features of the Liveweek event was the focus on CAD models and integration of the different IT systems. Many architects and engineers are already used to designing with CAD, but they all use different CAD implementations. Many CAD programs now have the capability of sharing information with other systems, but this is not always attempted in "real life" projects as it can raise some tricky technical issues. At Teamwork it was hoped that some of these issues could be resolved, and that an integrated, multi-faceted CAD model could be produced that incorporated designs from all the different disciplines involved. In addition to this, it was hoped that other computer data, such as cost analysis, and fabrication materials lists could be shared with those who required them for their IT systems. Clearly then it was anticipated that IT systems would have an important role in conveying information between the team members.

8.3 Rationale of the study

One of the first decisions to be made in this study was which parts of the Teamwork process to focus on, and when to collect data. Teamwork consisted of a number of pre-Liveweek meetings and events, and Liveweek itself. The pre-Liveweek events began some months before the Liveweek, and included introductory workshops, team-building sessions and seminars. Each team (there were six in total) also arranged separately to have a number of pre-Liveweek team meetings. At these meetings the design schemes were put together and discussed, the team members' roles were decided and a start was made on the basic design work.

Liveweek itself took place in June 2002. It was a week-long event, but split into two sessions with three teams in each session. On the final day of Liveweek, a conference was held, where each team was required to give a short formal presentation about their design, and on their experiences at Teamwork.

As a researcher, therefore, I had a number of options with regards to how to study the event. These included:

i) Studying the whole Teamwork process, from the set-up meetings and pre-design meetings through to the Liveweek event and post-event analysis
ii) Focussing on a single aspect of the whole event (including the pre-meetings, such as trust networks etc.)
iii) Focussing on Liveweek

Time and resource constraints prevented me from following the first option, although it was my preferred approach, as it would have given a more complete picture of the Teamwork communication networks than the other narrower fields of study. The second option was too focussed for the kind of network study that I wanted to conduct. Option three was convenient; focussing on Liveweek would provide a concise environment in which to collect data, within a manageable timeframe. It would, however, also be useful to follow some of the activities surrounding Liveweek, in order to contextualize my data. I therefore chose option three, with elements of the first option; I followed the event from the start, attending as many of the pre-meetings as possible, but focussed the data gathering on Liveweek.

In practice, the Liveweek event was to prove to be an ideal environment for the study. Firstly, it was a concise environment, everything was happening in one large room, so for observational purposes it was ideal. Liveweek also brought together new teams for the duration of the event, and so provided an opportunity to observe and record the development of the teams themselves. In the meetings prior to Liveweek the team memberships had not yet been finalised, and there tended to be different people present at every meeting. During Liveweek however, the team membership was much more stable with all of the core members of each team being present. This meant that recognising who was in which team was much easier to do.

The projects and tasks the teams were being asked to do were created specially for Liveweek, and it was intended that they would be brought to design completion within two days. This meant that I was able to collect data that represented the whole of the Liveweek design project, from start to finish, from early design concepts, through to preparation for manufacture. The teams were required to develop computer models of their design, and networked computers were provided with Internet connections, so the team members had IT connections with each other, and with the outside world. This provided an opportunity for me to observe how design concepts were created and shared using IT, and also how computer technology was used in a wider communicative sense.

The organizers of Teamwork were conducting their own "Knowledge Capture" study during Liveweek that was running in parallel with my own. This meant that I could compare my results with theirs at the end of the study, but also that my role as a researcher was readily accepted by the team members as part of the expected activities of Liveweek.

Finally, and significantly, the use of the RIBA hall for Liveweek meant that no one was on their "home turf", so that all of the team members were on an equal footing with regard to the work environment.

8.4 Methodological approach

The methods I chose to use for studying the networks at Teamwork were intended to identify whether a flow-form network was in existence, and if so, how the communicative flows were manifested. In the previous chapter I explained how a multi-methodological approach is one appropriate way of using existing analytical methods to investigate a flow-form network. For this study therefore, I chose to base the data collection and analysis of my study on such a multi-method approach. My intention was to conduct a number of different "sub studies", each looking at communication within the system in a different way. I was to use a different method of data capture and pattern-seeking analysis in each of these sub studies, then to look for recurrences of patterns across all of them. Recurrences of pattern, or correlation between the data sets, would suggest that the patterns reflected an intrinsic flow-form in the system. I chose to apply a three-pronged approach to collecting data, focussing on network structure, communicative content (as manifested in human dialogue) and the system's physical context (as represented by the use of artefacts, focussing particularly on computer-generated artefacts).

These three aspects were distilled into the following separate, yet interconnected sub-studies:

- Study 1 - The structure of interaction networks between team members
- Study 2 - Dialogic communication in the collaborative design process
- Study 3 - Use of computer-based artefacts as communicative tools

In addition to the three primary studies, I took notes of my own impressions of the event and the interactions that were going on. Although these notes did not contribute directly in the analysis, they proved to be a useful reference when I was analysing the other data. They also added contextual information that proved to be very useful later on in putting the results and discussion into order, and getting my impressions of the data together.

8.4.1 Some practical considerations

The teamwork context was likely to be very rich in potential data, and I wanted to make the most of this. My intention was to collect as much data as possible so that I would have a rich data pool for analysis after the event. I did, however, have to decide what kind of data I was most specifically looking for, and to work out how I was going to gather it.

The organizers of Teamwork had given me a free remit to collect data at the event; provided that I didn't hinder its progress, I was permitted to collect data in any manner I chose. After considering a variety of options, I decided that the simplest and least obtrusive approach was to take a role as "participant observer", joining the event in the capacity of "knowledge capturer". The Teamwork organizers had created a "Knowledge Capture Team", whose primary task during the event was to collect data on its progress, so I took a role as part of this team. So to all intents and purposes I was present as a member of Teamwork, taking part by collecting data on how the event was running. This to me meant observing what was going on and recording data, but not taking part in the design tasks or in the management of the event itself.

8.4.2 Study 1 - The structure of interaction networks between team members

From the outset, I knew that one of the things I wanted to do was to record the interactions that happened at Liveweek, in a way that captured their dynamics and flow-forms. In an ideal situation I would be able to generate the equivalent of a "fungal network map" or "ant foraging map" that represented where people had gone during Liveweek and who they had interacted with. In an ideal world, I wanted to be able to get everyone to dip their feet in some kind of "paint" at the start of the day, so that they would leave interconnecting trails of footprints showing where they'd been during the day.

Obviously the paint option wasn't possible, so I needed to find alternative methods for tracking the team member's activities during the period of Liveweek. Methods considered included recording the interactions of the entire population of Teamwork. This could have been achieved by using small cameras or badges that recorded encounters between team members; or it might have been done by videoing the whole event from a suitable vantage point (cameras in the ceiling?), that recorded who encountered who. This, however, presented a problem in terms of how team members would have been identified. Ideas that were suggested included asking team members to wear different coloured t-shirts or hats that identified which team they belonged to.

The notion of recording interactions was given serious consideration, and a number of designs for electronic badges that recorded interactions were postulated. Ideas included infrared detectors in the badges that recorded when they reached close proximity with another badge-wearer, or the similar use of Blue-Tooth technology in the badges. Unfortunately however, none of these methods however proved to be practical, or affordable at the time. Subsequently, a badge has been designed by others that might have worked in this environment (Choudhury and Pentland, 2003).

Eventually, the method chosen to record interactions was to simply observe the interactions that were happening at timed intervals in the hall. The method involved observing and noting at timed intervals who was interacting with whom, and their locations within the room. These data were recorded as maps that showed the various team members' locations and to whom they were near. The data thus produced were subsequently investigated for recurrent patterns using social network analysis, which included analysis using a SNA software package called UCINET (Borgatti *et al*, 2002).

8.4.3 Study 2 - Dialogic communication in the collaborative design process

Study 2 was intended to augment the results of Study 1. While Study 1 would show *where* people went during Liveweek, and with whom they interacted, Study 2 would indicate *what* people were communicating during these interactions; it was designed to capture some of the *content* of their interactions, as represented by their spoken dialogue.

Hand-held video recording was chosen to capture dialogue data. The benefit of using video, as opposed to audio tape is that, as well as recording *dialogue*, videoing also captures body language, and how artefacts such as sketches, computer terminals and so on are used. In contrast to Study 1, which recorded the interactions of *everyone* present in the Liveweek hall, for the video recording I chose to follow just one team. This made the recording simpler, and permitted the collection of in-depth content data. The resultant tapes were transcribed, and analysed for content.

The coding scheme for the Liveweek dialogue data was developed specifically for this study. It was, however, based on an established methodology known as *verbal analysis*, developed by Chi (1997). Verbal analysis is a coding and analysis method for spoken and written data, which seeks to integrate both *qualitative* and *quantitative* approaches. Initially, the data are transcribed, before being "segmented" into utterances, sentences, or other appropriate portions. These segments are then investigated *qualitatively*, and the trends, impressions and patterns that emerge are used to develop or modify an initial coding scheme. This coding scheme is then used to categorize all of the data segments, and finally *quantitative* analysis is used to describe and analyse the results.

The intention in this methodology is that the valuable aspects of both quantitative and qualitative analysis are integrated. So, the *quantitative* analysis is believed to minimise subjectivity, and generate results that are replicable, while the coding scheme itself has been generated in a manner that is intended to engender the *qualitative* trends and impressions that exist in the data.

Lipponen *et al* (2003) have used Chi's verbal analysis method in a situation that was broadly comparable to my own Liveweek study. Their study involved analysing a school class' use of a web-based "virtual" classroom. In a real-life classroom situation, students were given a project to complete, and asked to post information on the project to the virtual classroom and take part in the discussions there. Lipponen *et al* only analysed the data from the web environment; they did not collect any data from the physical classrooms. The data were analysed using both SNA techniques (to measure levels of online interaction of the students), and verbal analysis (to characterise the *content* of the online discussions). The set-up of this study was similar in some respects to my own, in that the researchers measured levels of interaction with UCINET (the SNA software package that I used), as well as characterising the content of the communication with verbal analysis. For the verbal analysis of my Liveweek dialogue data, I therefore chose to start the analysis with the coding scheme that Lipponen *et al* devised. As analysis progressed, however, my coding scheme was altered and adapted to better fit my own data. This process is described in greater detail in the procedures chapter of this thesis.

8.4.4 Study 3 - Use of artefacts as communicative tools

The artefact study was intended to relate the human interactions to *where* they took place, and to the *tools and objects* that were being used.

The data for this study had been collected by the organizers of Teamwork as part of their "knowledge capture" process, in the form of computer files that were collated onto computer CD and copies were distributed amongst the Knowledge Capture team. The CD data included CAD models at varying stages of completion, letters, emails, faxes, scans of sketches, and documentation written by the team members. Also included were screen shots taken hourly from the computers used by the teams, which the Knowledge Capture team had programmed to happen automatically. The major advantage of using these data was that they were being collected anyway by the Knowledge Capture Team, and because I didn't need to be involved directly in the knowledge capture, this left me to concentrate on collecting the other data. As it turned out, subsequently, I was the only researcher to systematically analyse the data captured by the Knowledge Capture team.

Like the dialogue study, for the artefact analysis I chose to focus on the one team: the same team chosen for the dialogue study. A huge quantity of computer data had also been collected from all the other teams, but it was simply not possible to analyse it all within a reasonable time. Focussing on a single team made the analysis for the artefact study much more manageable. The bulk of my analysis in this study concerned the screen-shot images. Each of these images provided a considerable amount of data, including who was using a particular PC, what computer program they were using, the file they were working on, the time that the image was taken, and so on.

The analysis of these computer files took the form of a basic content analysis. The images were categorised according to what kind of activity they showed, which computer terminals had been used to produce them, who had authored them and so on.

The content data from the image files were compared with and augmented by the other files on the CD's. So for example, a screenshot that showed a team member working on a particular CAD file was compared with the CAD file itself. Files such as these often have historical data attached to them, including who authored them, who worked on them and so on. Notes were taken of as many of these details as possible, for later correlation with the network and video data from Studies One and Two.

8.4.5 Integrating the data, comparing datasets, looking for repeated patterns

The data from each of the studies described above were first analysed in a manner appropriate to the data. So Study 1 was analysed using SNA, while Studies 2 and 3 were analysed (separately, using different coding schemes) for content. In carrying out these quantitative analyses, I was looking for *patterns* within the data of each study. In particular I was looking for patterns in the study that reflected flow-form network structures, such as:

- Communicative channels that expanded when the flow through them increased
- Network density (which might be represented by the number of channels or interactions) increasing as a response to increased flow
- Dynamic (or permeable) boundaries between teams
- Creation of cross-links between communication networks to facilitate flow within the network

In practical terms, I was looking for features such as repeated interactions between the same group of people in the network analysis, multiple occurrences of dialogue relating to the same topic or issue in the content analysis, or use of the same computer terminals by different people in the artefact analysis.

After analysing each of the studies independently, an integrated analysis was conducted on the data, correlating and comparing in detail the results from each of the three sub-studies. Here I was looking for patterns that were repeated across different data sets, which would indicate that the pattern was flowing between different modes of analysis, and may suggest flow patterns in the communication itself.

Meanwhile, I was continually reflecting on the methodologies themselves through an iterative process that continually questioned the integrity of the data, and whether the results I was getting were actually representations of what was happening in the network, or whether they were artefacts of the analysis methods. So I was considering:

- Whether the analytic nature of the tools might be causing over-abstraction of the data
- Questioning whether the multiple perspectives were generating a clear picture of the system
- Seeking new ways in which the tools and analysis methods could be adapted to provide a clearer insight into the flow-forms within the network.

8.5 Conclusions

Investigating flow-form networks in a human system was always going to be a challenge because of the analytical limitations of the methodologies available. In this study however, a decision was made to *use* these limitations as an opportunity to see how much one could actually achieve using such methods to study flow-forms. In one respect then, this was to be a study not only about human flow-form networks, but an evaluation of how analytical tools might be usefully applied to studying flow-forms.

In the meantime, it was hoped that by looking for repeated patterns across different kinds of communication data from the system, that I should get an idea of whether communication was flowing between people, their environments, and their tools; or whether the communicative flow was being impeded or disrupted.

The object of all of these investigations was to identify whether flow was at all apparent in the system being studied. Communicative flow might, however, not necessarily be a positive attribute; it could conceivably have a negative or degenerative effect. In this study however, no qualitative assessment was made about the nature of the flow, as this was considered to be beyond the scope of the current research.

Chapter 9 – Teamwork study: procedures

This chapter will give details of the methods that were used to collect and analyse data at the Teamwork event.

9.1 Situation of the study

9.1.1 Timing and location

The Liveweek of Teamwork 2002 was held during the week beginning Monday June 10th 2002. The hall where Liveweek took place was not large enough for all of the teams at once, so for this reason, the teams were divided into two groups. The first group, comprising three teams, took part on Monday and Tuesday of Liveweek. The second group, of four other teams took part on the Wednesday and Thursday. The Friday of Liveweek was devoted to presentations prepared and given by each of the teams.

The team I chose to study was part of the Monday/Tuesday group. So it was during these two days that I collected my data. I was also present on the Friday for presentations; however the data I recorded then were not used for my analysis.

Liveweek was held in the Florence Hall of the Royal Institute of British Architects (RIBA), 66 Portland Place, London. Florence Hall is located on the first floor of this imposing building. At the time of the study, it also housed a café that served visitors to the RIBA. There were two main entrances to the hall, both along the same side, and both exiting to the main stairway of the building. Opposite each doorway, running the entire length of the hall were two areas of seating and tables that were used by the café customers. This left a central area of roughly 20 metres square that was allocated to the Teamwork event. In this central Teamwork area were a number of grouped desks and chairs. Each team was allocated one of the desk areas. A schematic map of the Liveweek location is shown in Figure 9.1. On each group of desks were between 3 and 5 networked PC's. Each of these "team computer networks" comprised a "workgroup" that was connected to a central Teamwork server that was located at the far end of the hall near the Knowledge Capture Team's area. With the exception of the Knowledge Capture Team, Team members only had access to their own workgroup's computers. The Knowledge Capture Team were, however able to access any of the computers on the network. All of the computers had access to the Internet and Email.

Some of the large café tables on either side of the hall also served as meeting areas for the teams. These were used at irregular intervals whenever the teams wanted to hold a team meeting away from their working areas. The advantage of the café as a meeting location was that the circular café tables were large enough for all of the team members to sit around at one time, and to converse with each other as a team. The café tables were also large enough to hold structural drawings etc. so that every one could see them. This was not the case at the Team working areas, where the desks were irregular in shape and cluttered with computer workstations and so on.

There was one telephone in the hall that was used by Teamwork; it was located near to the Knowledge Capture Team's area. Many Team members however had their own mobile phones, which they used during the event.

To one side of the hall, next to one of the café areas, was a large outdoor balcony. This was accessed via a glass door to one side of the café area. Outside there were several café tables and chairs for customers of the café to sit at. This area was considerably quieter than indoors, and was occasionally used by team members when they wanted to work in a quiet area away from others.

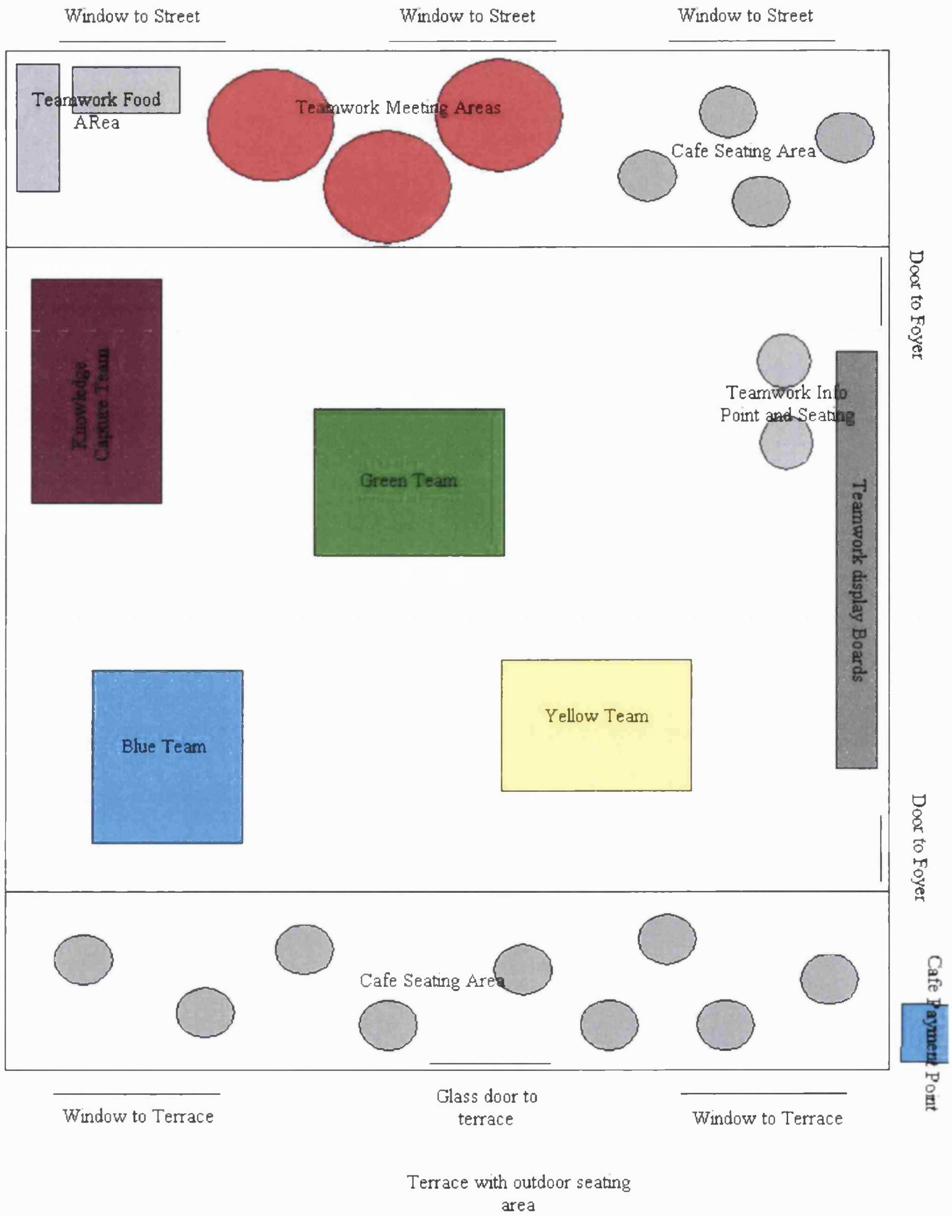


Figure 9.1. Schematic map of the RIBA hall where Liveweek was held

9.1.2 Access and consent

I was given permission to participate in Teamwork as an observer, and given unofficial membership of the “Knowledge Capture” team that had been put together to collect data during Liveweek. I was allowed to attend and observe a number of the pre-meetings (although I did not collect data at these), and also at Liveweek. In addition, I was given permission to approach a chosen team leader with a view to recording video data of themselves and their team at work during Liveweek. The first team leader that I approached declined, however the second accepted and so it was this team that I chose to follow during Liveweek.

9.1.3 The study population

The core participants in Teamwork were the members of the various design teams. Each team comprised ten to fifteen people in total, however on each day roughly eight to ten were present. On the days that I collected data, there were three teams present. They each named their teams, but for the purposes of this report, I shall refer to them as the Blue, Green and Yellow teams.

The members of these teams came from all areas of the construction industry and had a variety of specialist skills. They included architects, structural engineers, quantity surveyors, fabricators, services engineers (heating /ventilation/electrical systems specialists), and others.

The Blue team comprised members from just one (very large) company, but the other two teams were made up of members from various different companies. In all the teams, some of the members had worked together before, through both intra and inter-company collaboration, but not all of them. Each team had had a number of pre-meetings, but not all of the members had been to all, or even to any of these. So Liveweek was the first time that the members of the teams had worked together on a single project.

A number of the participants were non-native English speakers; this was most notable in the Green and the Yellow teams, who included members from Germany, Sweden, Portugal, Belgium and the UK. These members had a noticeable difference in spoken English skills. However, all communication during Liveweek was conducted in English, and no occurrences were recorded of other languages being used.

Of the team members (including the Knowledge Capture team) 91% were male, and 9% were female, although this ratio varied considerably on an individual team level. The age demographic was biased toward younger people. 51% of the team members were estimated to be between the ages of twenty and thirty, 24% with estimated ages between thirty and forty, 21% between forty and fifty, and 4% over the age of fifty.

On the two days that they were working on the design task, the participants all wore t-shirts printed with different logos according to which team they belonged to. The team members had designed the logos themselves during the meetings before Liveweek.

Apart from the core Team members, there were many other people present during Liveweek. The organizers of Teamwork itself were present during Liveweek, and formed a more loosely arranged group known as the "Knowledge Capture Team". The members of the Knowledge Capture Team were involved in the set-up, organization and running of Teamwork. During Liveweek, they moved from team to team, overseeing the design projects, advising the teams on what was expected, and collecting data on how the event was going. Most of the Knowledge Capture Team members were employed within the construction industry, however their role was to collect data on the event, rather than to participate in the design projects of Liveweek.

Also present were specialists from the IT industry. These included IT system designers, network engineers and CAD specialists, whose role was to set up, maintain, and advise on the use of the IT systems in use at Teamwork. Some of these people joined a particular design team, while others took roles as "consultants" within the Knowledge Capture Team during the week.

In addition to the direct participants of Teamwork, there were a number of visitors to Liveweek. These included members of the construction companies who had employees participating in Teamwork, and who wanted to see how it was going.

Finally, there were also a number of independent sales people, notably software salespeople, and a number of freelance management specialists who were involved in Teamwork, but who were not members of any specific team.

9.2 Overall comments on how the data were gathered

My position at teamwork was that of a non-participatory data-collector. I chose to focus the bulk of my data collecting activities on one team, and was accepted in this role by the team members. I stationed myself at that team's table, and moved with them when there was interesting data to record. Since I was also making observational recordings of the overall activities during Liveweek, I made sure that I was always positioned so that I could see the other teams in the hall.

Throughout this study, the team members were identified in the data by the initials of their first names and surnames.

9.3 Study 1 – The structure of interaction networks between team members

9.3.1 Data collection for Study 1

For this study, a record was made of interactions between people in the Liveweek venue. At approximately half-hour intervals, a hand-drawn map was made of the locations of all the people in the hall, their identities (if known) and which team they were a member of, if any. The teams had been given t-shirts with large logos on the back that identified which team they belonged to; this was used to establish team membership. If a person was not recognised as a member of any of the teams, they were marked as a "visitor". A total of eighteen maps were created in this way.

9.3.2 Analysis of data from Study 1

1. For analysis, the observation maps were transferred to a computer diagram drawing programme (Visio). The Visio maps were plotted on a grid background. This grid was used to identify who was interacting with whom: if two people on the map were no more than four grid squares apart, they were determined to be "next to" each other. Their proximity was taken to be an indication that they were probably interacting with one another (if not at the time of the map recording, then probably between then and when the next map was recorded half an hour later).

2. The interaction data from each map were entered into a computer spread sheet programme (Excel), as social network analysis matrices. A matrix was created for each of the eighteen maps. Another matrix was created that combined the interaction data from all of the maps. In contrast to the first set of matrices, which were binary, showing merely whether or not a particular interaction had occurred, the combined matrix was "valued"; the numbers in the cells indicated the *number of occurrences* of a particular interaction.

3. The data from all of these matrices were then exported to a specialist SNA computer programme (UCINET) for further analysis. Initially, the data were analysed using basic network statistics, such as counts of numbers of nodes and links, and network density.

4. To ascertain whether there were trends in the sizes (number of actors) or densities of the eighteen interaction networks over time, the size and density data were plotted as simple bar graphs, and the relations between them tested for correlation.

5. The centrality and betweenness values for each actor were calculated. These are both typical SNA measures, and were carried out using the UCINET software. The centrality score represents how many links that actor made with any other actors; it is a measure of how well connected a node is. Betweenness is a representation of the extent to which a node acts as a "liaison" or connector between other nodes.

6. A measure of "clustering" was also performed on the overall network data, to see whether members of the same team tended to interact together as a group, rather than with members of other teams. The tool used for this was another UCINET statistical measure, which was a form of ANOVA test.

7. The three different teams were also analysed separately, to ascertain whether the teams each contained actors with similar network roles, or whether any of the teams had characteristics that the others did not.

8. The data from the valued matrix (all the observation data combined) were then exported to another computer programme (named NetDraw), which generates visual "graphs" (network maps), from SNA matrices. Using this program, a single "interaction map" was created, showing who communicated with whom during Liveweek, and how often they did so. In this map, the widths of the lines used to connect nodes were determined by the number of times the interaction occurred.

9. This map was then examined for notable features. The kinds of features that were looked for included any strong links between actors, repeated interactions between the same groups of people, isolated individuals, and so on. The features that were identified were noted down for particular attention in the dialogue and artefact analyses.

9.4 Study 2 – Dialogic communication in the collaborative design process

This second study was conducted concurrently with Study 1. The object of this study was to collect and analyse the content of a single team's communication during their two days at Liveweek.

9.4.1 Data collection for Study 2

A single project team was selected and their actions video recorded over the week. No attempt was made to select particular individuals in the team for videoing, but a focus was made on recording as much dialogue as possible. When the team members weren't engaged in dialogue (which was usually when they were working independently on the design), video recordings were made of the work they were engaged in, such as views of computer screens etc.

The video recorder was set to show a real-time clock in the corner of the screen, so that all of the tapes contained a record of the time that the footage was recorded.

9.4.2 Analysis of data from Study 2

1. As discussed in Chapter 8, the procedure for analysing the dialogue collected for Study 2 was based on a methodology developed by Chi (1997), known as *verbal analysis,* which employs both qualitative and quantitative methods. The first stage was to catalogue the video material that had been recorded. This helped to identify and locate data from the videos later in the analysis. In cataloguing, the video data were unitised according to "scenes". A scene was deemed to have ended when the camera was paused, or recording was halted. A note was also made in the catalogue of the participants who took part in the scene, the time of the recording, the approximate length of the scene, a brief one or two line summary of the scene's subject, and an indication of the recording's sound quality (on a scale of 1 to 10, where 1 was poor and 10 was excellent.

2. After the data had been catalogued, a full transcription was made of every scene that included dialogue. It was decided that, although time-consuming, it was worth transcribing all of the recordings so that a full contingent of the data was available for content analysis.

The convention used to transcribe the data was derived from Silverman (2001) (see Appendix 1 for details).

3. Each scene was then analysed and coded for content, according to the *verbal analysis* methodology, which involves first investigating the data in a qualitative manner, to determine the coding categories that were to be used, before quantitatively analysing the coded data, as described in steps 4 and 5. The data were first segmented into appropriate fragments for analysis. In this study, segments were deemed to be “utterances” or “turns” taken by the speakers. Then a coding scheme was developed though qualitative examination of the data, where emergent patterns, such as repeats of similar kinds of statement, questions and so on were identified. In practice, a scheme developed by Lipponen *et al* (2003) who conducted a study in a similar computer-supported collaborative environment, was used as a start point. This scheme was first tested on a small portion of the data, and altered and adapted so that the categories became tailored to fit the patterns that emerged in the Liveweek data. Once the new scheme was finalized, it was used to code the entire data set. The scheme that was eventually used in this study appears overleaf(Table 9.1).

4. The coded results were entered into Microsoft Excel and investigated for recurrent patterns using Excel and SPSS. The total frequency (in the entire transcribed dialogue) of each kind of statement was calculated, as were the frequencies of statements in each of the six coding groups in the entire dialogue. The frequencies of statements in each coding group were also calculated on an actor-by-actor basis.

5. To see whether there were associative patterns in the kinds of statement used by each actor, correlation values were calculated on an actor-by-actor basis for all of the code combinations. So for example, the correlation value of code D (organizing the process) with code E (organizing the people) was calculated for each actor, to see whether the two kinds of statement tended to be associated with one another.

Content Analysis Coding Scheme			
Coding Group	Code Label	Type of utterance	Example from the text
Group 1 – Offering Information	A	Suggesting an idea (non-skilled, or non skill-specific)	SS: [we can do one for the landing on the moon with our team or something.
"	B	Providing skilled advice or suggestion of a positive nature (agreeing with another, or adding new skilled advice)	B SS: I think we can have columns (1.5) there
"	C	Providing skilled advice or suggestion of a negative nature (such as disagreeing with another, or saying they don't know something)	PB: You didn't want more than six hundred↓ (.) so you have to find some space
Group 2 - Organizing	D	Organizing the design process	SS: So I should actually give you (2) the SDNF files from the model (.) as it is now., (1) before the changes.
"	E	Organizing the people	SS: How much work do you still have today?/
Group 3 – Feedback and social exchange	G	Giving positive feedback ("that's good!", "nice work" etc.)	SS: yeh ((nodding)). That would be quite good
"	H	Giving negative feedback ("you muppet!", "that's stupid" etc.)	SS: don't say it so (0.5) cynical
"	N	Social exchange	SS: That (.) you know (2.5) Turkey hit the ball back to the one in, it was erm=
Group 4 – Statements about the design context	I	Contextualising statement (explaining what's being discussed etc.)	MW: I was working on the balconies right now.
"	K	Reporting a past action	SS: At the moment. (1) We're coordinating, you know, so that I know what every one is doing.

Table 9.1 Coding scheme used to code and analyse the video dialogue. I developed this particular scheme after having transcribed the video dialogue, but it was partly based on a prior scheme by Lipponen *et al* (2003). Continued overleaf…

Table 9.1. Continued from previous page.

Coding Scheme cont…			
Coding Group	Code Label	Type of utterance	Example from the text
"	L	Reporting an intended action ("what we are going to do is")	KR: Er: we're going to concentrate on the walls (.) er, using CADmeasure
"	M	Explaining the design, or explaining what is being shown	PB: (1) what (.) I assumed from this is (0.5) we had a box inside a box. (0.5) and this box inside a box actually had a roof on top of it (.)
Group 5 – Information-seeking statements	F	Stating a problem (identifying a problem)	PB: (2) and (.) I added (0.5) the stair (1) to get the truss through (0.5)? There we (.) run into some problems actually
"	J	Query	PB: And what about the columns?
Group 6 – Uncategorised statements	X	Not categorised	SS: oh.

9.5 Study 3 – Use of artefacts as communicative tools

9.5.1 Data for Study 3

Study 3 used computer data from Liveweek which had been captured on disk, to study how the team used artefacts.

At Liveweek, each of the teams had been provided with a small network of computers, comprising several computer workstations connected together via an Ethernet network. The team networks were also each linked to a central Teamwork server that managed the entire network. As part of the "knowledge capture" process of Teamwork, the organizers of Liveweek collated a series of CD's of the data files that had been produced by the design teams, both in the weeks prior to, and during Liveweek itself. These CD's contained a variety of different kinds of file, including:

- The design models that the team had produced (CAD models)
- Computer documents written by the team members, including letters, faxes, web pages, emails, and so on
- Screenshots captured at hourly intervals from each PC
- Scanned images of many of the paper sketches and handwritten notes that the teams had produced

9.5.2 Analysis of data from Study 3

All of the screen shot files on the data CD of the chosen team were analysed for content, according to a specially prepared coding scheme. The coding scheme is presented below:

Artefact Analysis Coding Scheme
1. File name of screen capture image
2. Computer name (either "Pooh", "Piglet", "Heffalump" or "Pootel")
3. Date shown in the screen shot
4. Time shown in the screen shot
5. Name of active computer file in the screen shot
6. Suffix of the active file in the screen shot (indicates file type)
7. Programme being used to access active file
8. Brief description of what is happening in the screenshot

Table 9.2 Coding scheme for Study 3 (artefact analysis).

The coded data were entered into Microsoft Excel. They were then investigated and analysed using Microsoft Excel and SPSS. Basic statistics were recorded, such as the mean number of times a particular program was used on each PC, the number of times each file was opened on a particular PC, and whether the same files were opened on different PC's.

In addition to the analysis of the screen captures, other files on the data CD were investigated. The data on these however were recorded in a more qualitative fashion. Notes were made of the file names, the kinds of file that they were, the author of the file (if it was recorded on the file itself), and general notes on the content of the files. Similar notes were made for the scans of design sketches. The primary intention with these notes was to use them for reference in the combined analysis where the artefact data were compared with with the network and video data from Studies 1 and 2.

9.6 Methods used to conduct combined analysis of data from all three studies

9.6.1 Relations between results of network structure and dialogue analysis (Studies 1 and 2)

To assess whether the social network analysis data and the content analysis results were associated in any way, a number of correlative tests were performed. Social network measures, such as betweenness and centrality were tested for correlation with the results of the dialogue coding.

9.6.2 Relations between results of artefact analysis and dialogue analysis (Studies 2 and 3)

The relations between the Content data from Study 2 and the Artefact data from Study 3 were investigated by a somewhat more qualitative approach than had been employed up until this point. A process of comparison and deduction was used to connect the dialogue captured in the video recordings with the screen shots captured from the Team member's workstations.

By looking for features such as matching times between the video recordings and the screen captures, or dialogue that related to computer files that had been produced by the team, more details regarding the way that artefacts and dialogue related were gleaned. Since the Team members had sometimes moved to different workstations, it was not always obvious in the screen capture data who had been working on a particular workstation at any one time, or who had authored a file. To deduce this, the *locations* and *actions* of the actors in the video recordings were scrutinised and compared with the content of the screen captures.

Having worked out who had authored or worked on each computer file, the artefact data were re-analysed with the user data included. Notes were made of who had used which files at which time, which of the workstations were shared and by whom, and whether any of the computer files such as CAD models were shared by multiple users on different workstations.

Chapter 10 – Teamwork study: results and analysis

10.1 Results of Study 1 - the structure of interaction networks between team members

10.1.1 Initial analysis

A total of 18 sets of observational data were collected, in the form of sketched maps of the Liveweek participants' locations. They were made at roughly half-hour intervals during the two days of Liveweek that were studied (Monday 10th and Tuesday 11th June 2002).

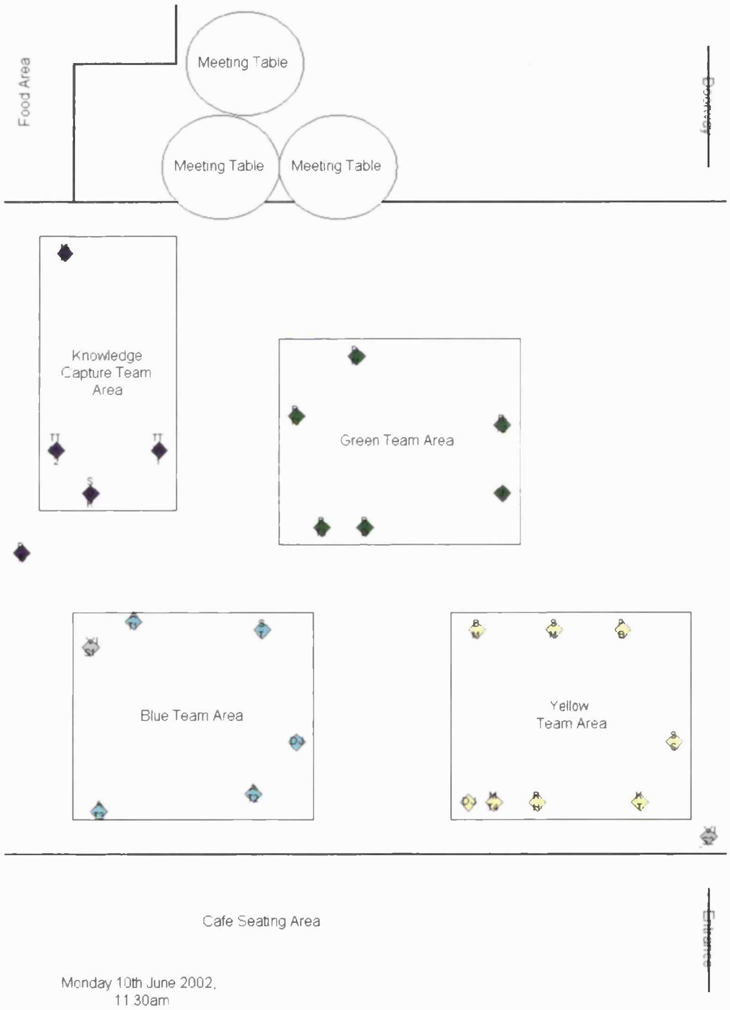


Figure 10.1 One of the eighteen maps of observed interactions, created from data collected during Liveweek. This map represents the first stage of data analysis, where the hand-drawn maps were transferred to Visio (a computer diagram drawing program). The map shows the approximate positions within the Liveweek hall of each of the actors at 11.30am on Monday 10th June 2002. Each of the coloured squares represents an actor, the letters indicate the initials of the actors; the colours of the squares represent each of the four Liveweek teams, the grey squares indicate that the actor was a visitor (not a member of any team).

	MP	PF	SDR	TTW1	TTW2	AT1	AT2	AT3	DJo	SF	DM	J	RD	RT1	RT2	RT3	DJ	KT	SM	BM	RH	MT4	PB	SS	VIS1	VIS2
MP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SDR	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TTW1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TTW2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AT1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
AT2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AT3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Djo	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
RT1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RT2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RT3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
DJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
KT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
BM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
MT4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
PB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
SS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VIS1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VIS2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 10.1 One of the eighteen matrices of Interaction Data, created from the maps of observed interactions, according to the method described in Chapter 9. The data in this particular matrix were collected at 11.30am on Monday 10th June 2002; this matrix was derived from the same data as those shown on the map on the previous page (Fig 10.1). It indicates which of the actors were interacting with one another at the time of observation (see Chapter 9 for details of how interactions were defined). The initials at the row and column headers are the initials of the actors that were present in the hall at the time the data were observed. A "0" indicates that no interaction between that pair of actors was observed, while a "1" indicates that an interaction was observed. N = 26. Shaded cells indicate actors who were members of the Yellow team which were subsequently the focus of video-recording in Study 2

The number of actors present on each of the observation maps varied between 23 and 36. The mean number of actors in each map on the Monday was 29.6, while on Tuesday the mean number of actors was slightly higher at 31.5.

Density is an SNA measure of the ratio of the number of actual links to the number of *possible* links in a network. A density value of 0 would indicate a network with no links between actors, while a value of 1 would indicate that all possible links had been made. During Liveweek, the densities of all the observed interaction networks were fairly low. They ranged from a very sparse 0.012 (recorded late on Monday afternoon) to a maximum of 0.049, which was recorded earlier on Monday afternoon. The mean density of the networks (from both days) was 0.030.

Data Set	**Time Recorded**	**No of actors in network**	**Density of Network**
1	Mon 11.30am	26	0.025
2	Mon 12.32pm	29	0.027
3	Mon 2.05pm	33	0.045
4	Mon 2.34pm	31	# 0.049
5	Mon 3.38pm	33	0.028
6	Mon 4.25pm	28	* 0.012
7	Mon 5.06pm	32	0.029
8	Mon 5.40pm	25	0.037
9	Tue 9.20am	* 23	0.024
10	Tue 10.01am	* 23	0.032
11	Tue 11.36am	33	0.026
12	Tue 12.25pm	32	0.018
13	Tue 1.25pm	30	0.029
14	Tue 2.45pm	35	0.020
15	Tue 3.34pm	# 36	0.025
16	Tue 4.28pm	32	0.043
17	Tue 5.06pm	# 36	0.037
18	Tue 6.20om	35	0.027

* = minimum values

= maximum values

Table 10.2 Summary data for all eighteen sets of observation data, showing the number of actors and the network densities (an SNA measure of the ratio of the number of actual links to the number of possible links in a network). For a complete collection of the results for all eighteen data sets (observational maps, interaction matrices, social network maps and summary SNA data, see Appendix 2).

10.1.2 Relations between network sizes and densities

To ascertain whether there were any trends in the number of actors in each network, or in the network densities, the size and density data were plotted as simple bar graphs, and the relation between them tested for correlation. The distribution of the number of actors appeared to be roughly bimodal (Figure 10.2), with a peak at around 2pm on each of the two days. This pattern however was not reflected in the graph for network density (Figure 10.3), which had a quite different distribution. A correlation test indicated that there was no significant relationship between the number of actors and the density of the interaction networks.

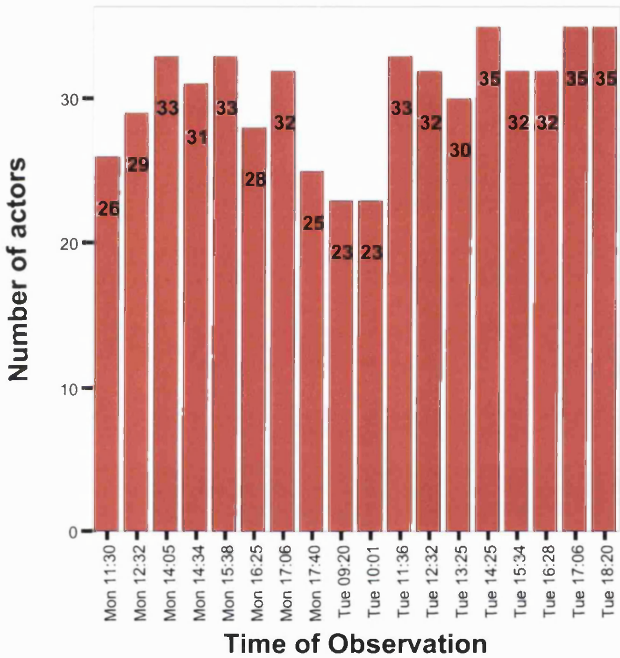


Figure 10.2 Graph of the number of actors at present in the Liveweek hall at timed intervals.

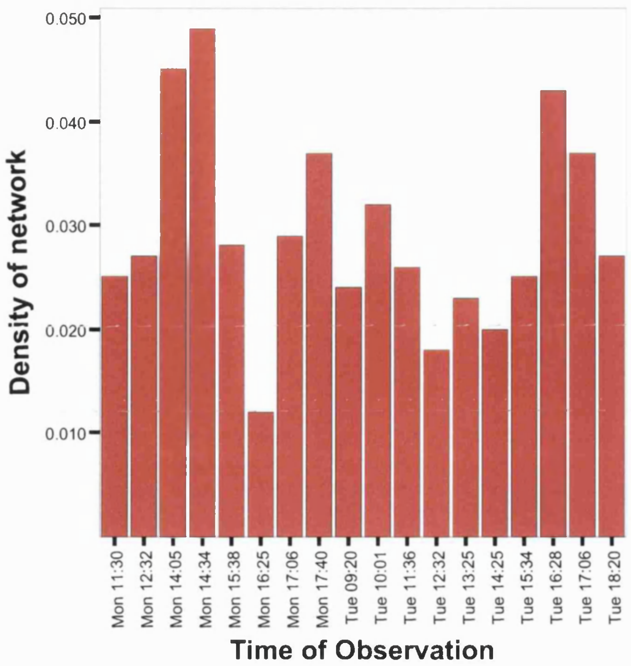


Figure 10.3 Graph of the densities of interaction networks observed during Liveweek. Densities were calculated on UCINET.

10.1.3 Analysis of individual actor characteristics

The centrality and betweenness values for each actor were calculated. These are both typical SNA measures, and were carried out using the UCINET network analysis software. The centrality score represents how many interaction links that actor made with any other actors; in network terms, it is a measure of how well connected a node is. Betweenness is a representation of the extent to which a node acts as a "liaison" or connector between other nodes.

The centrality and betweenness scores of all the actors are presented in Table 10.3. The actor with the greatest centrality score was SF, who interacted with other actors on twenty-six occasions, while the lowest centrality score was shared by three actors, AT7, RT5 and MC who all had scores of just one. The actor with the highest betweenness score was PF whose score was 13.4; a number of actors shared the lowest betweenness score of 0.

Actor's initials	Actor's Team	Centrality	Betweenness (normalized)
SF	Blue	26	7.4
AT3	Blue	23	0.0
AT2	Blue	22	0.6
AT1	Blue	20	10.6
AT	Green	20	7.2
BM	Yellow	18	0.3
PB	Yellow	18	2.8
AT4	Blue	17	0.9
SM	Yellow	17	0.8
GR	Yellow	16	1.3
MW	Yellow	16	3.6
VIS1	Visitor	15	7.7
VIS2	Visitor	15	9.7
KR	Yellow	13	3.9
DM	Green	13	3.6
PF	Knowledge Capture (KC) Team	13	# 13.4
Djo	Blue	12	3.1
KT	Yellow	12	1.6
SS	Yellow	11	1.7
J	Green	11	2.4
RH	Yellow	10	1.2
JN	Green	10	3.5
M	Green	10	1.4
RT2	Green	10	1.8
H	KC Team	10	9.4
SDR	KC Team	10	5.0
AT5	Blue	9	0.6
N	Green	9	2.4
MP	KC Team	9	5.8
DJ	Yellow	8	5.3
LD	Green	8	4.4
RT1	Green	8	3.2
VIS3	Visitor	8	7.2
FB	Green	6	0.1
RT3	Green	6	0.3
IM	KC Team	6	3.3
VIS4	Visitor	6	2.6
AT6	Blue	5	0.2
SR	KC Team	5	5.0
TTW1	KC Team	5	6.2
MT4	Yellow	4	0.0
RD	Green	4	0.6
RT4	Green	4	0.2
KC	KC Team	4	0.2
RT6	Green	3	0.1
RT7	Green	2	0.0
RT8	Green	2	0.0
AP	KC Team	2	0.0
CG	KC Team	2	0.6
RMcW	KC Team	2	0.0
TTW2	KC Team	2	0.0
TTW3	KC Team	2	0.0
VIS5	Visitor	2	0.2
AT7	Blue	1	0.0
RT5	Green	1	0.0
MC	KC Team	1	0.0

= maximum value

Table 10.3 Degree Centrality and Betweenness of each actor, sorted by Centrality value. These scores were calculated from a combined data matrix that collated all the data from the eighteen observation maps into a single table. Shaded cells indicate actors who were members of the Yellow team which were subsequently the focus of video-recording in Study 2

Team	Mean Betweenness of actors
Visitors	5.5
Knowledge Capture	3.5
Blue	2.6
Yellow	2.0
Green	1.8

Table 10.4 Mean betweenness scores of the actors in each Liveweek Team.

10.1.4 Clustering of actors

A measure of "clustering" was performed on the combined network data, to see whether members of the same team tended to interact together as a group, rather than with members of other teams. The tool used for this was another UCINET statistical function referred to within the software as "Network Autocorrelation", essentially it was a modified ANOVA test. In this case, the Network Autocorrelation function tested the hypothesis that actors prefer to interact with members of the same team. The result was significant to a level greater than 0.001, indicating that the clustering of the network nodes around team membership groups was non-random. In short, the results of this test showed there was a significant tendency for the team members to interact with each other, rather than to interact with members of other teams.

10.1.5 Relationship between density of network and links to non-team members

Although the centrality measures in Figure 10.3 show the *level* of interaction of each of the teams members, they do not show how many of the interactions occurred *within* or *out of* the teams; they merely indicate the level of interaction between team members and *any* other actors. To further investigate whether there was any relationship between a team member's activity level and the frequency of interactions they made within their own team, a scatter plot was made (Figure 10.4). This plot relates the *density* of an actor's personal network (known as an actor's *egonet*), which is an indication of the frequency of their interactions with others, with the frequency of links made *within* the team. The result, shown in Figure 10.4, suggests that there is a *positive relationship* between an actor's egonet size and the frequency of their interactions with fellow team members. A Pearson test for correlation found that the relationship between these two factors was significant to the 0.01 level. This correlation suggests that as an actor's egonet becomes more active (i.e. contains more interactions), the interactions are more likely to be with fellow team members than with "outsiders" who are members of a different team.

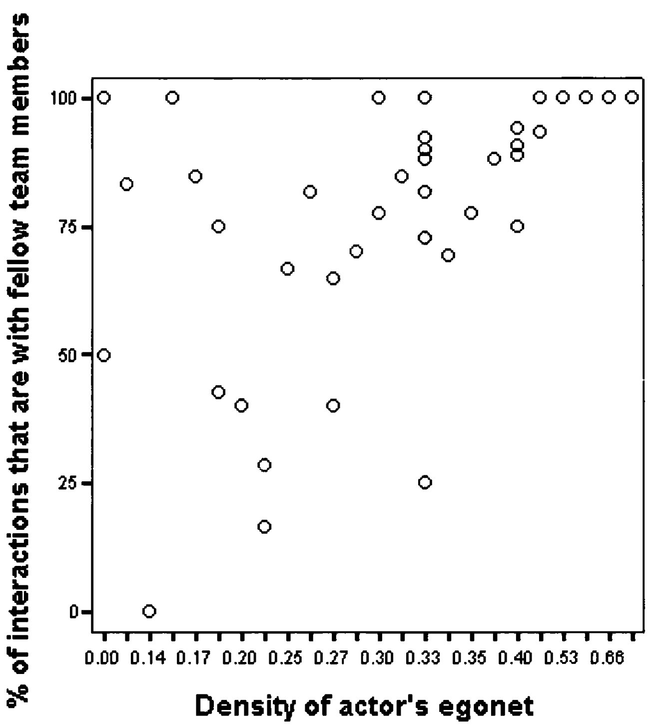


Figure 10.4 Scatter plot of the density of an actor's egonet (their own interaction network), against the frequency of interaction links they made with members of the same team as theirs. The positive correlation was found to be significant (P = <0.01, Pearson correlation)

10.1.6 Social network map of all interactions observed at Liveweek

Finally, the data from the valued matrix (all the observation data combined) were exported to another computer programme (NetDraw), which generates visual "graphs" (network maps), from SNA matrices. Using this program, a single "interaction map" was created, showing who communicated with whom during Liveweek, and how often they did so (Figure 10.5). In this map, the widths of the lines used to connect nodes were determined by the number of times the interaction occurred. This collated Liveweek interaction map was primarily created to generate a visual representation of the observed interactions. The general layout of the map was manually adjusted to group same-team nodes together, to represent the layout in Florence Hall where Liveweek tool place. The physical position of the nodes on the map is not therefore significant. What is important however is a) the variations in tie strengths between nodes and b) the variations in connectedness of the nodes. It is immediately obvious from the map that the Blue team was more strongly connected internally than the others, while the least strongly connected team seems to be the Knowledge Capture team.

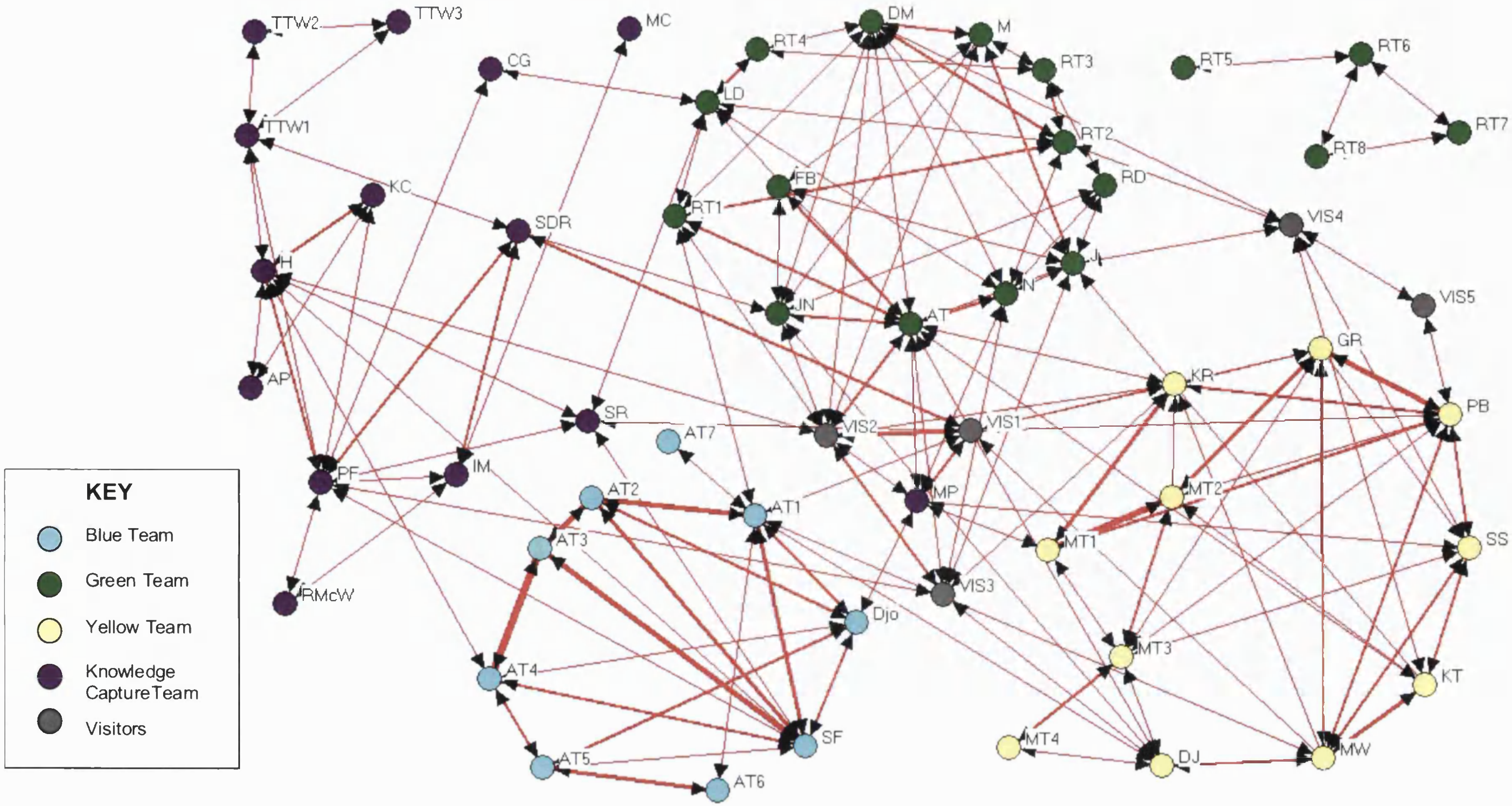


Figure 10.5 Map of all Observed Interactions During Liveweek. The data in the combined data matrix were transformed into a graphical output using Netdraw. The resulting sociogram shows all interactions observed during Liveweek. Each of the nodes represents an actor, while each node is coloured according to the team to which the actor belonged. The lines between the nodes represent occurrences of interactions. The thicker the line, the more frequently the interaction occurred. The arrangement of the nodes has been manually altered slightly to represent the general positioning in Florence Hall, with each team member positioned roughly in the place where they spent most time during Liveweek.

10.2 Results of Study 2 - Dialogic communication in the collaborative design process

The aim of the video-recording had been to collect as much activity and dialogue on video from a single team as possible. The team chosen for videoing was the Yellow team, so the bulk of the video data was focussed on members of this team, resulting in some 10 hours of video-recorded activity. Not all of the recorded sequences contained dialogue, recordings were also made of team members working on their computer workstations, sketching designs and so on, so the video recordings were initially catalogued so that incidences of dialogue could be identified for transcription.

10.2.1 Actors' skills and roles

From the dialogue, and from general observations, the principal skills and roles of each participant in the transcribed dialogue were deduced. These are shown in Table 10.5.

Actor	Team of Actor	Gender of Actor	Nationality of Actor	Role
BM	Yellow	Male	British	Services engineer
DJ	Yellow	Male	British	Steelwork draughtsman
GR	Yellow	Female	Portuguese	Architect
KR	Yellow	Male	British	Quantity surveyor
MW	Yellow	Male	British	Structural engineer
PB	Yellow	Male	Swedish	Architect
RH	Yellow	Male	British	Services engineer
SM	Yellow	Male	British	Services engineer
SS	Yellow	Female	Belgian	Structural engineer, Yellow team leader
AT	Green	Male	British	Technical consultant on steelwork software
MP	Knowledge Capture	Male	British	Knowledge Capture
SR	Knowledge Capture	Male	British	Knowledge Capture

Table 10.5 Identities, genders, nationalities and roles of the actors whose dialogue was transcribed from the video data recorded at Liveweek. These were deduced from the video dialogue, and from notes taken during Liveweek.

10.2.2 Overall results of the dialogue coding

All of the video-recorded dialogue that involved members of the Yellow team was transcribed and coded according to the coding scheme presented in Chapter 9. The data were broken down into 56 "scenes" that ranged between 0.5 and 26 minutes in length. Eight of these scenes were recorded during Team Meetings. A total of 2211 utterances were transcribed and coded.

The total frequency (in the entire transcribed dialogue) of each kind of statement was calculated, as were the frequencies of statements in each of the six coding groups in the entire dialogue. The greatest number of utterances fell into Groups 1 and 2: Offering Information, or Statements about the Design. The smallest coding group was Group 3, Feedback and Social Exchange.

A summary of frequencies of the coded utterances appears in Table 10.6.

<table>
<tr><th>Coding Group</th><th>Number of Utterances</th><th colspan="4">Subcategories</th></tr>
<tr><td rowspan="2">1 – Offering information</td><td rowspan="2">405</td><td>Code A</td><td>Code B</td><td>Code C</td><td></td></tr>
<tr><td>9</td><td>307</td><td>89</td><td></td></tr>
<tr><td rowspan="2">2 – Organizing</td><td rowspan="2">274</td><td>Code D</td><td>Code E</td><td></td><td></td></tr>
<tr><td>179</td><td>95</td><td></td><td></td></tr>
<tr><td rowspan="2">3 – Feedback and social exchange</td><td rowspan="2">75</td><td>Code G</td><td>Code H</td><td>Code N</td><td></td></tr>
<tr><td>51</td><td>10</td><td>14</td><td></td></tr>
<tr><td rowspan="2">4 – Statements about the design</td><td rowspan="2">405</td><td>Code I</td><td>Code K</td><td>Code L</td><td>Code M</td></tr>
<tr><td>70</td><td>122</td><td>30</td><td>183</td></tr>
<tr><td rowspan="2">5 – Information-seeking</td><td rowspan="2">306</td><td>Code F</td><td>Code J</td><td></td><td></td></tr>
<tr><td>97</td><td>209</td><td></td><td></td></tr>
<tr><td rowspan="2">6 - Uncategorized</td><td rowspan="2">764</td><td>Code X</td><td></td><td></td><td></td></tr>
<tr><td>764</td><td></td><td></td><td></td></tr>
</table>

Table 10.6 Summary of coding of all of the Yellow team members' dialogue that was videoed and transcribed during Liveweek. The table shows the frequencies of each category of statement uttered. The meaning of each code is as follows:

A - Suggesting an idea (non-skilled, or non skill-specific)

B - Providing skilled advice or suggestion (+ve, agreeing with another, or adding new skilled advice)

C - Providing skilled advice or suggestion (-ve, disagreeing with another, or saying they don't know something)

D - Organizing the process

E - Organizing the people

F Stating a problem (identifying a problem)

G Giving +ve feedback ("that's good!", "nice work" etc.)

H Giving –ve feedback ("you muppet!", "that's stupid" etc.)

I Contextualising statement (explaining what's being discussed etc.)

J Query

K Reporting a past action

L Reporting an intended action ("what we are going to do is")

M Explaining the design, or explaining what is being shown

N social exchange

X Not categorised

10.2.3 Utterance types used by each actor

The coded utterances were then considered on an actor-by-actor level, where the distributions of utterances in each coding group by the individual actors were examined. The results of this are presented in Table 10.7.

	Percentage of Total Utterances In each Code Group					
Actor	Group 1 Offering information (A, B, C)	Group 2 Organizing (D,E)	Group 3 Feedback and social exchange (G,H,N)	Group 4 Statements about the design (I,K,L,M)	Group 5 Information-seeking (F,J)	Group 6 Uncategorized (X)
AT	17 (0,14,3)	24 (17,7)	3 (3,0,0)	10 (0,0,0,10)	7 (3,4)	38 (38)
BM	38 (30,8)	0 (0,0)	0 (0,0,0)	15 (0,8,0,7)	8 (8)	38 (38)
DJ	14 (0,14,0)	7 (0,7)	0 (0,0,0)	24 (0,9,3,10)	17 (7,10)	38 (38)
GR	21 (0,18,3)	5 (3,2)	3 (2,1,0)	25 (2,8,1,14)	7 (2,5)	39 (39)
KR	19 (1,15,3)	7 (5,2)	2 (2,0,0)	25 (3,8,4,10)	16 (6,10)	31 (31)
MP	0 (0,0,0)	0 (0,0)	0 (0,0,0)	15 (0,0,15,0)	23 (0,23)	62 (62)
MW	31 (0,23,8)	10 (6,4)	7 (4,1,2)	13 (3,3,1,6)	12 (3,9)	27 (27)
PB	14 (1,10,3)	7 (5,2)	3 (3,0,0)	19 (4,5,3,7)	17 (7,10)	41 (41)
RH	38 (0,27,11)	2 (0,2)	1 (1,0,0)	18 (3,4,1,10)	13 (10,3)	28 (28)
SM	10 (0,7,3)	0 (0,0)	7 (4,3,0)	17 (0,17,0,0)	30 (3,27)	37 (37)
SR	11 (1,8,2)	4 (2,2)	2 (1,1,0)	10 (5,1,0,4)	30 (3,27)	43 (43)
SS	10 (0,7,3)	24 (16,8)	3 (2,1,0)	19 (4,6,1,8)	11 (5,6)	32 (32)

Table 10.7 Distribution of utterance types for each actor. Figures are percentages, (but may not add up to 100% due to rounding effects). The figures in brackets show the percentage of utterances in each respective sub-category within the group (which are identified in the column headers).

The actors whose dialogue primarily concerned *offering information* were BM and RH, both of whom were services engineers. The actor who offered the least information was MP, who was part of the Knowledge Capture team. MP also had a high score in the information-seeking category, as did SR who was also part of the Knowledge Capture team.

SS, the team leader, as was to be expected from her role, produced a high number of utterances in the organizing categories. Another actor who had a high score in this category was AT, who was actually a member of another team who spent some time working with the Yellow team, and it was not immediately obvious why he scored highly in this category. The other actor who had a fairly high number of utterances in the organizing category was MW. This was interesting, as it seemed that on occasions where there was conflict between MW and SS for who should perform the role of team leader. Interestingly, MW also had a high score in Group 3 (feedback and social exchanges), which may suggest that in his efforts to secure a leadership role, he also engaged in more social interaction than the other team members.

For all the actors a high proportion of their utterances fell into Group 4 (statements about the design). DJ, GR and KR all had particularly high scores in this group. This coding group included categories I (contextualising statements), K (reporting a past action), L (reporting an intended action) and M (explaining what is being shown).

10.2.4 Correlations between utterance types

On closer inspection, it became apparent that there could have been a relation between the scores of each actor in Group 1 (offering Information) and Group 5 (information-seeking). Actors that have a high score in the "offering information" categories often seemed to have a low score in the "information-seeking" categories, and *vice versa*. To test whether there was a relationship between these two categories, a Spearman rho correlation test (chosen because the data were not normally distributed) was performed on them. The correlation between the variables was found to be significant to the 0.05 level. A scatter plot indicated that the relation between the variables was indeed negative (Figure 10.6), that is to say, as the number of "information-offering" utterances increased, the number of "information-seeking" utterances decreased. The level of significance is not high, but it does suggest that the actors who sought the most information (asked questions, raised problems etc.) were not the actors who offered most information or answers.

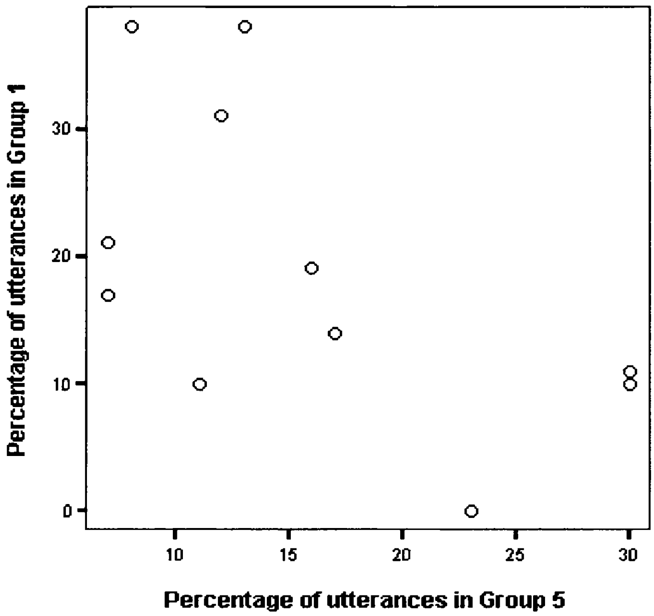


Figure 10.6 Scatter plot of the relationship between the total utterances (of all team members whose dialogue was transcribed) in Coding Groups 1 (offering information) and 5 (information-seeking). There is a negative correlation between these variables that is statistically significant to a 0.05 level of probability.

10.2.5 Uncategorized statements

Finally for Study 2, it was noted that the number of statements in the "uncategorized" group (Group 6), was fairly similar for all the actors at around 30-40%. These statements mainly represent inaudible utterances, or non-verbal utterances such as laughter. The exception to the pattern was MP, for whom 62% of his utterances couldn't be categorised. In this actor's case, it's primarily a reflection of the fact that he had a very quiet voice that didn't record clearly and so many of his utterances simply couldn't be heard on the video recording.

10.3 Results of Study 3 - use of artefacts as communicative tools

Screen captures had been made from four different PC's, this was an automated process, originally set up by the Knowledge Capture Team. They were named (by the Knowledge Capture Team) as "Heffalump", "Pootel", "Piglet" and "Rabbit". A total of 299 screen images were captured, these were all analysed for content according to the scheme presented in Chapter 9. A total of 12 different computer programs were used by the members of the Yellow Team; these ranged from Computer Aided Design (CAD) programs, to a word processing package (MS Word), and a number of different web sites. Unsurprisingly for a design team, the program that was used most frequently was Autodesk, a computer aided design package, this program was in use in 230 of the 299 screen capture images. The next most frequently used program was a word processor package (MS Word), but this appeared only 30 times in the screen captures, so was used relatively infrequently compared with the CAD program. Other programs were used intermittently by the team members, the most significant was Navisworks. Navisworks is a program that imports data from different CAD models, to create an integrated representation of the building in a "virtual reality" form, which allows the user to "walk through" the structure as if holding a video camera. It also detects whether there are spatial conflicts between the different imported CAD models; in this way architectural, structural, services models and so on can be superimposed and checked against one another.

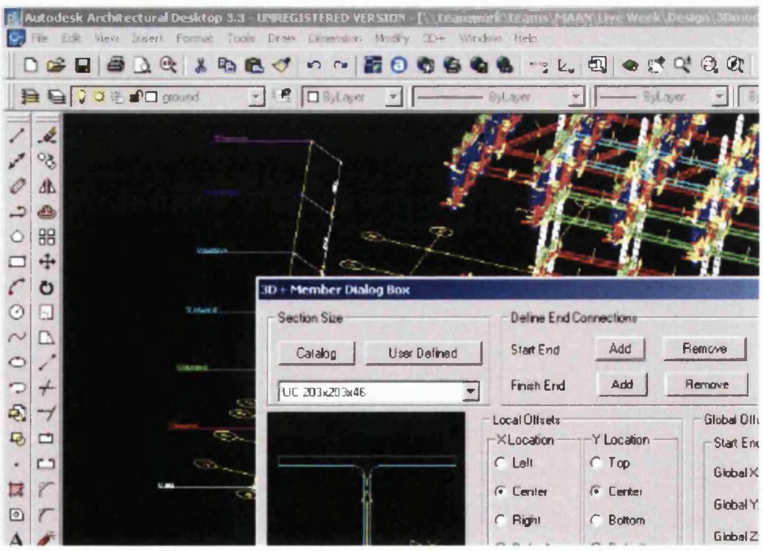


Figure 10.7 Part of a typical screen capture. This image shows that Autodesk is the active program, also just visible at the top right hand corner of the image is part of the name of the file that was in use at the time.

Program	Program Description	Number of times program was active in screen captures
Adobe Acrobat	document viewer	1
Autocad	CAD program	3
Autodesk	CAD program	230
DOS Command Prompt		1
MS Excel	spreadsheet program	1
MS Word	word processor	30
Navisworks	Three-dimensional CAD walkthrough program	6
Outlook Web Acess	for accessing email on a remote server	5
Pronet	document management system	1
Teamwork Web Site		1
Windows Explorer	file browser	11
Microstation installation program		1

Table 10.8 Names, descriptions and frequencies of appearance of various computer programs in the screen capture images taken during Liveweek. A total of 299 screen captures were made. A program was deemed to be active in the image when it was shown as selected in the image (identified by a blue bar at the head of the program window).

Outlook web access was used by the users of the workstations called Heffalump and Rabbit. This program was used for sending and receiving emails from the users' remotely situated company offices. This is noteworthy because it indicates that they were maintaining contact with people outside of Teamwork.

The analysis of the data collected for this artefact study is however relatively brief. This is because most of the detailed analysis of the screen capture images was conducted through cross-referencing the screen capture data with that from the video content study (Study 2). Those results therefore will be presented in the next section of this chapter, which describes the results of the combined analysis data from all three studies together.

10.4 Results of combined analysis of data from all three studies

10.4.1 Relations between the Social Network and Dialogue data (Studies 1 and 2)

To assess whether the social network analysis data and the content analysis results were associated in any way, a number of correlative tests were performed. Factors such as an actor's betweenness, centrality and size of egonet were tested for correlation against each of the coding categories from the content analysis. A Pearson correlation test was chosen since the data from the content analysis were categorical and therefore non-normal in distribution. The results of these tests are presented in Table 10.9.

Network Measure	Content Data Coding Categories													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Size of actor's egonet	N/S	N/S	N/S	0.05	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S
Betweenness	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S
Centrality	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S
Density of egonet	N/S	0.05	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S
% total links to members of the same team as the actor	N/S	0.05	0.05	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S

Table 10.9. Results of correlation tests between various network measures of Yellow-team actors at Liveweek (results of Study 1) and the number of statements they uttered in each code category in their dialogue (results of Study 2). Figures show significance level. N/S = Not significant. A Pearson correlation test was applied. (N = 12, which represents the total number of team members whose dialogue was analysed). Three of these relationships were deemed to be significant.[1]

The meaning of each code is as follows:

A - Suggesting an idea (non-skilled, or non skill-specific)
B - Providing skilled advice or suggestion (+ve, agreeing with another, or adding new skilled advice)
C - Providing skilled advice or suggestion (-ve, disagreeing with another, or saying they don't know something)
D - Organizing the process
E - Organizing the people

[1] [1] Note, the significant results for % total links to members of the same team as the actor with codes B and C were counted as a single positive result, as they both represent the offering of information.

F Stating a problem (identifying a problem)
G Giving +ve feedback ("that's good!", "nice work" etc.)
H Giving –ve feedback ("you muppet!", "that's stupid" etc.)
I Contextualising statement (explaining what's being discussed etc.)
J Query
K Reporting a past action
L Reporting an intended action ("what we are going to do is")
M Explaining the design, or explaining what is being shown
N social exchange

Of the 84 correlation tests that were performed on these data, only three revealed any significant relationships between the Social Network data and the Content data. Those that were significant were only marginally so, and since the sample size is small (n=12) it is possible that these correlations are co-incidental.

However, if the results of these correlative tests are treated as revealing true connections between the data, they suggest that:

- The size of the actor's network was positively correlated with the number of utterances they expressed to organize people (Code D).
- The density of the actor's network was positively correlated with the amount of positive advice and suggestions they offered to others (Code B).
- The percentage of links that an actor made with fellow team members was positively correlated with the amount of both negative and positive advice and suggestions they offered to others (Codes B and C)

10.4.2 Relations between the dialogue and artefact data (Studies 2 and 3)
A process of comparison and deduction was used to connect the dialogue captured in the video recordings with the screen shots captured from the Team member's computer workstations. From this, the general layout and positions of workstations and their users in the Yellow team area were deduced.

Figure 10.8 and Table 10.10 and show the approximate layout of the machines and the users with which they were most often associated.

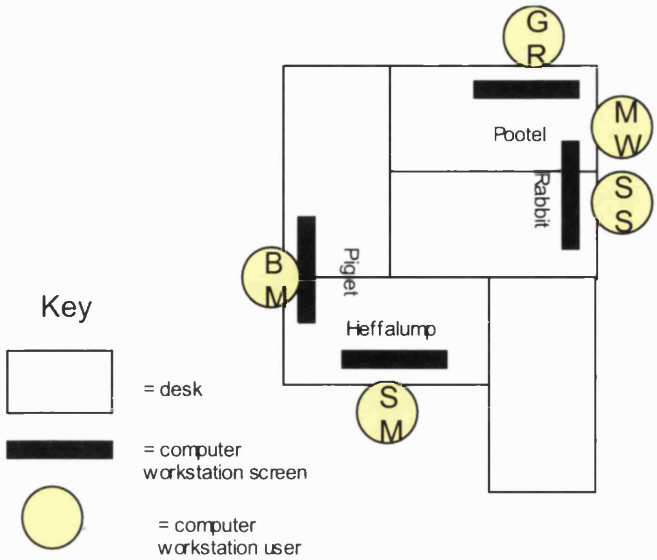


Figure 10.8 – General Layout and Positions of Workstations and their Users in the Yellow team area. The initials are those of the team members who were seated in that location most often.

Workstation Name	**Actor**				
	BM	**GR**	**MW**	**SS**	**SM**
Piglet	99				1
Pootel		100			
Rabbit			30	70	
Heffalump					100

Table 10.10 Summary of workstation use by the Yellow Team members during Liveweek. The workstations were named "Piglet", "Pootel", "Rabbit" and "Heffalump". Figures are percentage use, measured by occasions that the user was recorded as using that workstation in a screenshot.

10.4.3 Percentage use of the different programs

The data presented in Table 10.8, which showed the programs used to produce the files in the screenshots, were reanalysed to represent the *actors* who used these programs. Although CAD programs were used by all of the actors, their usage patterns varied. CAD programs were used for between 58% and 92% of the files opened by each user. SS and SM used MS Word for word processing quite frequently, mostly to record knowledge capture data. Table 10.11 shows the percentage of total files opened in Autocad (the primary CAD program used), and MS Word.

	Percentage of total files opened in these programs				
	BM	GR	MW	SM	SS
Autocad	90	92	81	58	63
MS Word	4	1	15	21	17

Table 10.11 Frequencies of use of Autocad (a CAD program) and Word (a word-processing program) by the members of the Yellow team during Liveweek. Figures are percentages, representing the percentage of the total number of files seen in the screen capture images by each actor.

10.4.4 File sharing between users on different workstations

A total of 7 files were viewed by more than one actor (on different workstations). One of these files was viewed by three different actor. All the files that were shared were CAD models. File use by the various actors is presented in Table 10.12.

Filename	Description of file	User 1	User 2	User 3
Ancillary space GF	Architectural CAD model	GR (2)	SM (2)	
Ancillary space IF	Architectural CAD model	GR (1)	BM (1)	
A-sheet section A&D FINAL	Final architectural model	SS (1)	GR (1)	
A-sheet section A&D sightlines	Sightline study (architectural CAD model)	GR (29)	SS (3)	
E100	Electrical services model (CAD)	BM (44)	SM (1)	
M200	Ductwork CAD model (services)	BM (25)	SM (1)	SS (1)
Site_v8	CAD Layout of entire site (all the team's buildings)	GR (1)	SS (2)	

Table 10.12 Files shared between actors. The source of these file names is the library of screen-capture images collected from the Team's workstations during Liveweek by the Knowledge Capture Team. Users of the files were deduced by cross-referencing these files with images and dialogue recorded on video during Liveweek for Study 2. Figures in brackets after the team member's initials indicated the number of times they appeared to be using that file in the screen-capture images.

Chapter 11 - Teamwork Study: Discussion

11.1 Discussion of the results of Study 1 (network analysis)

11.1.1 Initial analysis

The eighteen maps of interactions observed during Liveweek produced a graphic record that was easy to interpret visually, while the interaction matrices (and their associated social network analysis) put numbers to these observations, helping to determine whether the visual differences noted between the maps were significant.

What was immediately obvious was there *were* differences between the maps; the number of actors present during Liveweek, and the level of interaction between them varied considerably. The network density measurements indicated, however, that the overall level of interaction between actors was relatively low. The highest possible density value for any network is 1 (which indicates that all possible links between actors were made), while the minimum value of 0 would indicate that no links were made between actors. At Liveweek, the mean network density was just 0.03. This indicates that the actors were not interacting with as many others as they could: rather they were choosing to interact with just one or two people at a time, and often with no-one at all.

11.1.2 Relations between network sizes and densities

The bar graph in Figure 10.2 shows that there was a bi-modal distribution of the network sizes during Liveweek. The peaks in the graph indicate that the number of people present at Liveweek was greatest just after lunchtime on both days. My own observation notes suggested that the augmented number of actors at these times could have been due to an influx of *visitors*. Among the people who visited Liveweek were colleagues of the team members, representatives of various interested organizations, and a few members of the general public who simply wanted to see what was going on. These people would pop in to the Liveweek hall for a while to watch or chat with the team members, but did not stay all day. By contrast, the core team members who were actually working on the design projects tended to remain in the Liveweek venue all the time. The fact that the peaks in actor number were recorded in the middle of both

Liveweek days is probably explained very simply, as the visitors had often done so during their lunch breaks.

Section 10.1.2 in the results chapter demonstrated that the sizes of the interaction networks observed during Liveweek *did not* correlate with their network densities. This is a little unexpected as one might have thought that as the number of actors increased, so too would the level of interaction within the networks, whereas the result indicates that there was no relationship between the number of actors and the level of interactive activity. The reason for this is likely to be a reflection of the demographic of the networks. As mentioned above, the larger networks were often generated by the arrival of visitors, who might have had somewhat different interaction patterns from the core team members. These visitors to Liveweek may simply have wanted to *observe* what was going on, or they may have arrived to meet someone in particular, or they might have taken a while to get involved in interacting with others – perhaps watching a while before striking up a conversation with members of the design teams. The picture is complicated by the fact that a number of the new arrivals, in particular on the Tuesday, took roles as temporary team members and I recorded them as such, rather than as visitors. A notable example is the Green team, who on the Tuesday afternoon were joined by four new temporary members, which raised the Green team's membership by a considerable proportion. With patterns of influx and change such as this in the system, it's small wonder that the patterns of interaction and network size do not closely match.

11.1.3 Analysis of individual actor characteristics

The individual centrality and betweenness scores (which were presented in the results chapter in Table 10.3) begin to break down the observation data to show how the behaviours of *individual* actors at Liveweek varied. The centrality scores, which indicate how many interactions each actor made during Liveweek, show some considerable variation. From the centrality scores it is apparent that a wide spectrum of levels of interaction were represented at Liveweek, from actors such as SF, who was observed interacting with others on 26 occasions, to MC who was only once seen interacting with another actor.

Interestingly, the centrality scores of the Knowledge Capture team were all relatively low. I had believed that members of this team might have the highest centrality scores, as I had expected them to interact with many other team members in an effort to collect much data and information on how the event was running. In actuality, most of the Knowledge Capture team seemed to spend a lot of time working alone and in isolation, often at their computer workstations. Possibly they felt that they had set the event in motion, and by that stage it should "run itself". Nevertheless, it seemed to me that there was a huge amount of data to be collected simply by watching what was going on and chatting with the participants, and I was surprised that the Knowledge Capture team was not more frequently engaged in such activities.

The betweenness scores of the individual actors represent the extent to which a node lies "between" other nodes in a network. Betweenness can indicate those actors that behave as "bridges" or "liaisons" between other actors. Many of the actors at Liveweek had fairly low betweenness scores, but what is interesting is that the highest mean betweenness scores are those of the Visitors' group and the Knowledge Capture team. The actors in both of these teams were not involved practically in the design activity, so they were not required to remain with a single team to work on a design project. This meant that they were more free to move between teams, and for members of the Knowledge Capture team this was their expected role, as they were supposed to be moving between different teams organizing the event, gathering data and distributing information. So while the centrality scores of the Knowledge Capture team indicate that they did not interact as *often* as other actors, they did tend to *liase* between the different teams more often and this is reflected in their higher betweenness scores. The visitors' high betweenness scores could also suggest that they tended to move between teams more than the actors in the design teams. In this case, it was likely that the visitors were moving from team to team to observe what was happening in each one, and looking at the different design projects.

11.1.4 Clustering of actors

The ANOVA test for clusteredness showed that there was a significant tendency for members of the same teams to interact with one another, rather than to interact with members of other teams. On first impression, this finding seems to state the obvious; the teams would naturally spend more time working with each other than outside of their teams, that is after all the reason that the teams were put together. The result of the clustering test is, however, worth pointing out because it shows that the participants at Liveweek did actually engage in team-like behaviour, rather than dispersing their interactions between many different teams, which might have occurred, had they not been fully committed to their team's design project.

11.1.5 Relationship between density of network and links to non-team members

The results in section 10.1.5 indicated that there was a positive correlation between the density of an actor's personal network (their egonet) and the frequency of links that were made by that actor to fellow team members. This correlation suggests that as an actor's egonet becomes more active (i.e. it contains more links), the interaction links are more likely to be with fellow team members than with "outsiders". This kind of pattern was also discovered by Wellman (cited by Scott, 2003), who found that in family networks, there was also a correlation between network density and the proportion of members within who were kin. He concluded that family networks are denser because the relatedness between family members encourages network members to maintain mutual contacts. The fact that a similar pattern was found in the teams at Teamwork might suggest that this is also the case for fellow team members. Perhaps this was a sign that an atmosphere of "team spirit" was emerging, prompting the actors within the teams to interact more often with members of their own team than with those of others.

11.1.6 Social network map of all interactions observed at Liveweek

The "Map of all Observed Interactions During Liveweek" (Figure 10.5) was primarily created to generate a visual representation of the observed interactions. The image that it offers is striking, and to my mind is the clearest way of representing the organization of the interaction networks that developed over the course of Liveweek. From this map we can clearly see that some of the teams were organized differently from others, and how. For example, the Blue team comprises actors who are strongly connected as a team, interacting many times with each other; meanwhile, the Knowledge Capture team is far more loosely connected, both within the team and outside of it. The Green team comprised many actors, some of whom created their own separate sub-network (actors RT5, RT6, RT7 and RT8), which didn't interact at all with the other Green team members.

Another aspect that the network map highlights is the variance in levels of connection of different nodes. For example, it's clear on the map that characters such as MC, RMcW and CG don't have many connections to others in the network, while nodes such as AT, SF and DM have many. The visual distinctiveness of some of these nodes corresponds with some of the network measures calculated by the UCINET analysis software. For example MC RMcW and CG all have both low centrality and betweenness scores, while AT, SF and DM have high centrality and betweenness scores. The map therefore made some of the patterns and structures in the network *visible* and readily recognisable; in essence it was a way of representing the numeric data and matrices in a highly accessible form.

11.2 Discussion of the results of Study 2 (dialogue study)

11.2.1 Actors' skills and roles

In Table 10.5 in the results chapter, I presented the principal skills and roles of each participant, along with their genders and nationalities. Determining the roles of the team members (namely whether they were architect, engineer etc.) was often difficult, and the team member's roles were certainly not immediately evident to me during Liveweek while I was collecting the data. It was only after many repeated viewings of the video data while I was transcribing the dialogue, along with detailed inspection of my own notes, and consultation with other members of the Knowledge Capture team that I could be sure that I had identified the roles correctly. I believe that this was primarily due to the fact that the overwhelming majority of the participants of Liveweek were members of the construction industry, to whom the parts played by various team members were immediately evident because they were so familiar with the construction environment and people within it. I, however, as a researcher with little in-depth knowledge of the construction industry struggled to work out what each team member's speciality was, whether it be architect, services engineer, technical draughtsman and so on; all these roles were unfamiliar to me. Nevertheless, this process of identifying each of the actor's specialist roles was very important with regards to the later analysis of the data. It enabled me to work out things such as who was working within their own specialist domain (critical when determining whether an actor was offering specialist advice to another), and to identify when team members took on work in a role to which they were not accustomed (such as when one of the engineers assisted with the theatre stage design – which was primarily an architectural issue at the time).

11.2.2 Overall results of the dialogue coding

The table in the results chapter that shows the summary of the dialogue coding (Table 10.6) highlights some interesting patterns. Other than the uncategorized statements, whose frequency was unfortunately fairly high, the two most frequently uttered kinds of statement were those that concerned offering information, and those that were statements about the design. This was not unexpected, as during Liveweek one could have predicted that many of the dialogue exchanges would have concerned sharing of design information between actors. The high number of queries (code J) also reflects this, as actors were asking questions in order to gain information. The least frequently uttered statements, however, were social exchanges and feedback utterances. This was surprising, one might expect that in a collaborative open-plan environment the level of social exchange and reflective comment would be high. Perhaps the low incidence of these kinds of utterances indicates that the focus at Liveweek was on the work in hand rather than on social interaction, possibly because the time scale of the event was so short, meaning that the pressure to complete the task at hand was very strong.

11.2.3 Utterance types used by each actor

Table 10.7 in the results chapter shows the distribution of utterance types for each individual actor. At this stage in the analysis the value of having determined the roles of each actor became obvious. Having worked out who in the team were architects, services engineers, computer specialists and so on, it was possible to put each actor's dialogue into context. For example, two actors shared the highest percentage of utterances in Coding Group 1, which represented utterances that *offered information*; these actors were BM and RH. Both of these actors were services engineers, who spent much of their time during Liveweek working on CAD models of the building's services features, such as electrical cabling and air duct systems. BM was working primarily on two-dimensional models of these systems, while RH worked on three-dimensional models, eventually producing a three-dimensional "walkthrough" model of the building and services that could be "played" to show a virtual walk through the building on the computer. Consequently, these two characters were working with detailed technical information, and part of their roles during Liveweek was to communicate this technical information to the other team members. BM was actually one of the characters that spoke least during the whole of Liveweek, but when he did communicate, it was often in answer to a direct query regarding his work. For example, during one of the team meetings, while the engineers were explaining progress on the engineering model so far, he added:

BM: We've kind of focussed on the panel

And later in the same meeting, when asked by the team leader (SS) how long it would take him to finish the CAD model, this was his response:

SS: When do you think the electrical model will be: ready?
BM: E:m (2) in abo:ut, two hours I think. (2)

Similarly, at one point when RH (who was generally much more talkative than BM) was working with SS, the team leader, to solve a design problem, said:

RH: put a little upstand. (1) Which you'd probably have anyway, in the masonry, to make the connection.

All three of these utterances were coded as utterances that *provided information*. They are also examples of responses that *only* BM or RH could have provided, as they had the particular skills and insider design knowledge that meant they knew the answers.

To return to some of the other actors, MP had a particularly low score in the information-offering category (Code Group 1), and a correspondingly high score in the information-seeking category (Code Group 5). SR also had a high score in the information-seeking category, although he didn't have a particularly low information-offering score. These two characters were notable as they were not part of the Yellow team (who were the focus of this dialogue study), but members of the Knowledge Capture team. Their dialogue with the Yellow team members primarily concerned the gathering of knowledge and information on how the teams were progressing, hence their high information-seeking scores. SR however also had a role as one of the organizers of the event; so some of the team members went to him for advice on what was required of them as participants of Liveweek. This then explains his why his information-offering score was not particularly low.

SS was the team leader, a role that had been decided by the team members in meetings prior to Liveweek. Unsurprisingly then, it was SS who had the highest score in coding Group 2 (Organizing statements) of all the team members. This included high scores for both subcategories in this group, i.e. statements that organized *people*, and statements that organized *process*. Of the other team members, the only actor whose score for organizing statements approached SS's was MW. The interaction between SS and MW in the dialogue was interesting, with a few apparent skirmishes between them for control of the team. This wasn't particularly exposed in the dialogue analysis, as I was not trying to measure aspects of control or of power within the group. In flow form networks however, power struggles could have some impact on the networks' configuration. For instance, in fungal mycelium, which is an example of a natural biological flow-form network, power struggles between networks (individual flow-forms) can result in the formation of "demarcation zones" which neither individual will cross (Rayner, 1997). In future work, it could be of interest to study the impact of power struggles on human flow-form systems.

11.2.4 Correlations between utterance types

One of the questions that emerged during the dialogue coding was whether there was a reciprocal relationship for each actor between the scores of information-seeking and information-offering statements. In other words, did the people who asked the most questions offer the least information and *vice versa*; were some people the "question-askers" and others the "question answerers"? To solve this, I conducted the correlation test between Codes in Group 1 (offering information) and those in Group 5 (information-seeking) (see Figure 10.6). The results of the correlation test implied that there is indeed a weak negative correlation between them. This suggests that the people who sought the most information in the team were not the same as the people who offered information. I found this particularly interesting when considered within the wider context of this study. What is possibly being highlighted here is that were *directional* flows of information within the team, with requests for information (questions and queries) flowing in one direction between actors, and the responses were reciprocally flowing back. This pattern could have been analysed further by conducting a *directional* network analysis on the team's communication. In such an analysis, two networks would be considered concurrently, the first concerning who asks for information, and the second dealing with who provides it.

11.3 Discussion of the results of Study 3 (artefact analysis)

Since the Yellow team's task was to design a building, it was not a surprise to find that the most common use of computers by the team members was for working on computer aided design (CAD) files. CAD files made up the vast majority of the data collected in the Knowledge Capture team's screen shots. Nevertheless, a number of different uses of the computers are also apparent in the screen images. For example, a number of the workstations were used for word processing and writing documents. This is probably a reflection of the many reminders from the Knowledge Capture Team for the design teams to document their work. Other computer programs that were occasionally used included one that was used by team members to access remote email. This was of particular interest, because it indicated that team members were creating and maintaining communication links with people outside of the Liveweek hall. Electronic communication of this kind was not captured by the network analysis in Study 1, but it represents some of the ways that the team members maintained links with those outside of Liveweek.

The results of the artefact study alone are relatively brief, and to my mind not particularly illuminating. This was because very little could be deduced from the data in isolation. Once the artefact data had been combined with the video data, I was able to make comparisons between the two, which allowed me to determine the users of each computer workstation and every computer file. At that point, the artefact analysis took a big step forward. It was then possible to compare the programs and files used by different team members, to work out who had used which workstations, and most significantly, whether files had been shared between different team members working on different workstations. The results of the artefact study are therefore discussed in much more detail in section 11.4.2, where I deal with relations between the artefact data from Study 3 and the dialogue content data from Study 2.

11.4 Discussion of combined analysis results

The results of this study do, I feel, begin to come alive when the three separate sub-studies are related to one another. In reality, for this part of the analysis the data were considered in a somewhat "holistic" fashion, where all the data and analysis thus far were put together and considered as if there were no boundaries between them; *any* pattern that emerged during this combined analysis was considered seriously. However, for the purposes of clarity, I have presented the results of this process (in the previous chapter), and my discussion of the results (in this chapter) in a more structured fashion, and according to what I found. So, I have dealt firstly with relations between the Network Analysis of Liveweek (Study 1) and the Dialogue Content Analysis (Study 2), and subsequently with relations between the Dialogue Content Analysis (Study 2) and the Artefact Analysis (Study 3).

11.4.1 Relations between the social network and dialogue content data

As I discussed in Chapter 7, if there had been strong correlations between the data from the individual sub-studies, it would have suggested that I had discovered a consistent pattern of communicative flow within the system. The results from all fourteen of the dialogue coding categories were tested for correlation with five of the network measures that emerged from Study 1. In total therefore *seventy* potential relationships between the two data sets were tested for statistical significance. But, after this comprehensive testing, only three points of significant correlation were found between the two data sets. Nevertheless, although the correlative relationships between the two data sets were limited, they did exist, and this suggested that perhaps I had found some factors that might have been weak indications of flow-form patterns. As indicated in the results chapter in Table 10.9, the three factors that correlated with each other were as follows:

- The size of the actor's network (from Study 1) was positively correlated with the number of utterances the actors expressed to organize people (Code D from Study 2). To my mind, this makes perfect sense, as it suggests that those actors who were most influential in organizing the actions of others tended to have the biggest networks. If one is organizing a team of people, or a process, then it makes sense to try to work with many of those people as possible, rather than with just one or two.

- The density of the actor's network (from Study 1) was positively correlated with the amount of positive advice and suggestions they offered to others (Code B from Study 2). This also seems logical. Density of the network is a representation of how many links they made within their network, compared with how many links they *could* have made. Those who offered most advice and suggestions to others might not necessarily have had the largest networks, but they were communicating *often* with the people within their own network. Being an advice-giver, or one to whom others turn to for solutions seems a very effective way of integrating with others and consolidating one's position within a team.

- The percentage of links that an actor made with fellow team members as opposed to actors from other teams (a result from Study 1) was positively correlated with the amount of advice they offered to others (Codes B and C from Study 2). This result actually corroborates that found in the previous paragraph, as it suggests that those who gave advice tended to give that advice to members of their own team, rather than to members of other teams. Perhaps this is another indication of how actors established their positions within their teams, developing a role as a person to whom others turned to find out specialist knowledge; it also suggests that information was shared within teams, but not outside of them.

11.4.2 Relations between artefact data and content data

I have already described in the results chapter the qualitative process of comparison and deduction that was used to connect the dialogue captured in the video recordings with the screen shots that were captured from the Yellow Team member's computer workstations. In this manner it was deduced that of the four workstations, three were each used principally by one team member, while the fourth was shared between two team members. Both these team members, MW and SS were structural engineers, but SS was the team leader. The video record shows that SS actually spent a considerable amount of time working with pencil and paper, preparing documentation, process maps and other records of the activities of the team.

11.4.3 Percentage use of different programs

Table 10.11 showed that there were three team members, MW, SS and SM who, as well as working with CAD programs, also spent a fair proportion of their time using a word processing package. The files that they worked on with the word processor were primarily documents about the team's experiences of Liveweek, and the Team's web page. MW in particular became more frequently occupied with documentation in the latter part of Liveweek, and the video transcription suggests that he finished his CAD model fairly early, certainly long before any of the other models were completed. The dialogue excerpt below (Figure 11.1), shows that SS actually delegated part of the organizational work to MW because he had finished his CAD model early. This explains why he shares some of the documentation work with SS, and also explains why he has a relatively high frequency of utterances in the dialogue that were concerned with organizational activities (Coding Group 2).

SS: How much work do you still have today?/

MW: Nothin.

SS: You've stopped?

MW: Yeh I'm not doing any more on this three dee model, it's futile.

SS: so actually you're free.

MW: I'm free.

SS: free to (and do the)

MW: yeh (1) yeh (3) yeh, stuff like that. (1) Cos this model it's good, it's a full three dee (part of the) model. It just won't have the elements, I mean there's no point (wasting on that).

SS: yeh. (2) Make sure you have ((inaudible))

MW: [the prom (.) the prominent geometrics. (1) That's what I'm doing now.

SS: And you are still around anyway, to coordinate, (1) you know (what else we've done) there's loads of stuff. (3). If you're happy to.

MW: (2) yeh↑

Figure 11.1 Excerpt from a transcription of video-recorded dialogue, recorded during the second day of Liveweek (10.19am on Tuesday 11th June 2002). SS (female) and MW (male) are both structural engineers in the Yellow team. SS is the Yellow team leader, but in this dialogue, after learning that his work on the CAD model is nearly complete, she delegates some of the organizational responsibilities over to MW.

11.4.4 File sharing between users on different workstations

Table 10.12 showed that from the total of 299 files that were identified in the screen captures, there were seven files that were used by more than one team member, on different work stations at different times. All of these files were CAD models, but each was a different version of the design model, ranging from architectural models, to models of the ductwork and services, to a sightline study of the view that the audience would have of the theatre stage. There were two interesting patterns that seemed to emerge from the sharing of these files. Firstly, there were two engineering models, both of which were viewed on different occasions by different engineers. This suggests to me that these models were either being worked on by several engineers, or perhaps that the files were being passed from one engineer to another for checking or appraisal of some form.

The second pattern was in the use of the shared architectural models. Three of the architectural models were viewed separately by an architect and an engineer. In these cases, one would assume that the architectural models were created by the architects, then subsequently they were viewed by the engineers. There are a number of reasons why the engineers might have wanted to look at the architectural models. Perhaps the engineers needed to check the architectural design model to find out what parts needed to be considered in terms of engineering; or perhaps they were referring back to the architectural model to try to solve a design problem.

The passing of files between different team members seemed to me to be a very important finding. It indicated that computer files were being used by team members as a means of communicating with each other. The dialogue communication was therefore being augmented by computer-based communication, through use of the the design model.

One of the key issues that was supposed to be addressed by Teamwork was that of interoperability between the different forms of CAD model, such as those produced by the architects, structural models, services models and so on. This was clearly taken to heart by the team members, who encountered a number of difficulties when they tried to connect the models from the separate disciplines into a single integrated model. Inconsistencies between the models were a persistent issue, and this was discussed on a number of occasions by the team members. What is interesting is the way that the shared physical context of Liveweek enabled a number of such issues to be dealt with more easily than they often are in "real life" construction projects. Rather than having engineers and architects located a long way apart in different offices, or even different companies, Liveweek put them next to each other, so that they could discuss the integration issues in person, and with the computer models in front of them. In the dialogue excerpt below, SS, an engineer, and PB, an architect discus the differences between their respective CAD models by physically pointing out the same areas in the two different versions of the models on their computer screens (Figure 11.2).

PB: if I look at this section, ((looking on his computer screen))
SS: yeh
PB: if, say you have (1) a column (2) ((pointing with mouse on computer screen)), then I have to start trimming this (1) to make er:
SS: yeh but if you have yours-, you don't see anything on your (.) elevation. (2)
PB: my section?
SS: you don't even see the structure or-
PB: (we also have the structure) The structure is part of the section, part of the architecture

Figure 11.2 Excerpt from a transcription of video-recorded dialogue, recorded during the second day of Liveweek (11.02am on Tuesday 11th June 2002) between PB, an architect, and SS, a structural engineer in the Yellow team. They are both looking at their own computer screens, which each show their own versions of the CAD model. PB's is the architectural version, while SS's is the structural version. In this dialogue the team members are using their CAD models to communicate how their particular versions of the design correspond with one another.

Significantly, this dialogue again illustrates how the two different computer models were used as communicative tools. In this instance the computer models were being used as a medium for transdisciplinary communication. Both the architect and the engineer were working on the same overall design model, but they were looking at different "versions" of it on their computers, an architectural version, and an engineering version. The fact that they both had these models visible to each other on their computer screens meant that they could identify areas of similarity, and of difference, and still understand how these variations related to their own view of the design.

11.5 Overview and critique of the study

Overall, while the results of this study are not conclusive, they *are* positive. At the outset, I suggested that if there were patterns that recurred between the different data sets from Studies1, 2 and 3 (network analysis, dialogue analysis and artefact analysis), it was likely that a flow-form network was present. As I have explained in detail above, I did indeed find some correlation between the data sets, and certain features in the data were repeated in the three sub-studies. Unfortunately however, the correlations between the patterns that were found were not particularly strong. So, while the presence of a flow-form network at Liveweek is supported by the data, it is not supported very strongly.

In this penultimate section of the Liveweek discussion, I shall discuss what might have prevented the correlations between the different data sets from being expressed more clearly, and what more could have been done to bring greater clarity to the results.

11.5.1 Possible reasons for lack of strong relationships between the datasets

One aspect that might have affected the data in all three studies was the sampling method. For reasons of time and other resources, the samples in the more detailed dialogue and artefact studies (Studies 2 and 3) were smaller than the network study (Study 1). The network analysis was conducted for the whole system, taking into account the interactions of everyone at Liveweek. By contrast, the dialogue analysis concerned the interactions of just one team (the Yellow team, which comprised 11 actors), while the artefact analysis dealt with just four computer workstations (used by five Yellow team actors). The intention was that the more time consuming dialogue and artefact studies would act as a micro-level examination of the system, while the network study was looking at the same system at a macro level. It is possible however, that using a small sample for the dialogue analysis caused some of the patterns apparent in the larger scale system to be cut out. Perhaps if a wider analysis of the dialogue at Liveweek had been conducted, analysing the dialogue of everyone, rather than just a single team, some patterns may have emerged more strongly. It is possible that some of the patterns in the network were indeed also apparent in the dialogue and artefact data, but since the latter were from such a small sample, they weren't strong enough to be statistically significant.

Another factor that may have affected the correlation between data sets might have been the frequency of the observational "snapshots" that were recorded for the network analysis. For example, the interaction data were recorded at hourly intervals, but this left out many of the interactions as they occurred in between the times when the observations were made. So actors such as GR and MW of the Yellow team appear from the network analysis not to have had any contacts with non-team members. However, my observation notes, along with the video data indicated that they did have contact with others, but perhaps not for extended amounts of time. In fact, these two actors had one of the most important out-of-team roles as participants in an inter-team design project, but since these inter-team meetings did not last long, they were not recorded on the networks. This could point out a need to have taken more frequent observational data, but it also highlights the problem with taking "snapshot" type recordings. One simply doesn't know from the data what has been missed.

One issue that I suspect had a major contributory effect on the lack of correlation between the dialogue and network analyses was the way in which an "interaction" was recorded in the network study. In practical terms for this study, whenever two or more people were positioned in close proximity they were deemed to be interacting. A more complex study with unlimited resources may have captured these interactions in more detail; with perhaps video or audio capture devices being assigned to each Liveweek participant. In fact, a number of such devices were considered for use in this study, but in the end the financial cost was simply too high. So the simpler means of correlating interaction with close proximity was devised. Since the observational data were collected more or less hourly, it wasn't in my view unreasonable to assume that between each observation, if people were seated or stood closely together, they would have interacted or conversed in some way.

The problem however comes in trying to relate the dialogue analysis (Study 2) with the network analysis (Study 1). Non-verbal communication was not analysed in Study 2, nor was the effect of sharing the same physical contexts, but these factors might have had an effect on how the team members were interacting with one another. People sitting next to each other may be looking at the same thing, listening to the same talk (from across the table), sharing facial cues and body language and so on. Actors in close proximity to each other would also have been subject to similar contextual factors. For example, those who were located near the restaurant would have been exposed to the same food smells, noises and so on; they would also have the same issues with their computer workstations if the cable connecting the network to the Internet were unplugged.

If the results of the network study and of the dialogue study *were* to correlate closely, it would indicate that "interaction" always involved dialogue. Since they do not, it does suggest that interaction involved more than dialogue alone, and that some of these other aspects were playing a role.

11.5.2 What the methodology left out; the space around the numbers

As a researcher of flow-form networks, I found the analysis of the data from the Liveweek study both fascinating, and incredibly frustrating. Time and again it felt as though I was tantalisingly close to finding something important, but the analysis methods fell just short of being able to express what it was. Having studied network flow systems in the past, I felt convinced that the success of Liveweek, which many of the participants reported, was due, at least in part, to a communicative flow of some form. But that kind of "hunch" just was not permitted under the methods I had chosen for analysing the event.

Liveweek was an exciting event, with a definite "buzz" to it. The people there were enthusiastic about what they were doing, excited about their projects, and very positive about the things they were learning that they could take away with them to their everyday workplaces. This I felt was simply not captured in my analysis. The cold hard facts of who talked with whom, the structure of their conversation and the kinds of computer files they used, seemed to leave out all that was *vital* in Liveweek. If I hadn't been there, the results would suggest to me that it was a pretty boring event. I know that it was not. There was an element of "humanness", of individuality and sheer intangible "magic" of the event (which was also reported by many others who were there) that was not expressed at all by my analysis.

The impossibility of expressing these intangible aspects was immensely frustrating. Having transcribed, analysed and coded the dialogue, I *knew* that there were moments of tension, laughter, confusion, excitement and so on. There was for example, a moment where the first walkthrough model of the design was finished by one of the team members. The news of this rippled through the team and before many moments had passed there was a crowd of excited team members standing around the computer looking at the model. They said things like "*It's cool that you can walk in the ducts like that*" and "*look at that, that is impressive*", but these bald statements do not, and indeed cannot capture the intangible feeling of excitement and curiosity over the model. Even I as a researcher who hadn't worked on the design was interested. I remember (and noted) getting up and hurrying over to join the group of team members clustered around the workstation to see what was going on. And the model *was* exciting and intriguing to see. I could see the clashes in the model where a steel truss obstructed an air duct, I got an idea of the scale of the stage, and significantly, I finally got to see a three-dimensional image of the theatre building that the team were working so hard to design. How does one capture those elements in a research study? I certainly didn't in the quantitative transactional analysis that I've presented here. Would a qualitative study have been better? Perhaps so, but that may have missed other features. More to the point, since the key outcomes of Liveweek seemed to me to be intangible and unpredictable, how would any researcher have known before the start of the event, which kind of method would have been most appropriate?

I would suggest that what I have noted as a limitation of my Liveweek study, actually points to the limitation of the methodology in general. One of the questions I sought to answer through this study was whether we could use analytical methodology to gain insight into a human flow-form network. It seems to me that we can, but it is by no means a complete solution. I have learned things through my analysis that I could not have discovered through a more qualitative analysis, patterns have emerged that could *only* have emerged through analytical study. Yet aspects are still lacking. The issues point again to the way that when data are treated in an abstracted or reductionist manner, it can have a major effect on the picture that emerges. The methodological issues of my Liveweek study are reminiscent of the problems associated with the Lumeta Internet map, which I discussed in Chapter 7. Because I was present at Liveweek, I *know* that the people at teamwork were interacting, and that the content of their information exchange *did* relate to the manner in which they were interacting. The analytical investigation of the data suggested, however, that there is only weak correlation between the *structure* of the interactions and their communicative *content*, when one would expect the correlation to be much stronger.

What has become evident, both during the data collection at Liveweek, and in my subsequent analysis of the data is just how vital it is to retain an awareness of exactly what one is doing with each of the tools. For example, the network analysis was trying to make sense of the data through a process of *reduction*. Overall observations and interactions were *reduced* to a series of maps of nodes and interactive links. *Meaning* however could only be given to this reductive analysis by re-associating the results with the *context* in which they originated. It would not have been possible for me to connect the patterns seen in the results with their contextual meanings if I had not been personally present at the event, and without my detailed notes of impressions of what was going on, I would have been stumped at many points in my analysis. I knew what made sense and what did not in my data because I had *been* at Liveweek, I had seen things happening, and knew what it felt like to be involved.

11.5.3 Liveweek as a flow-form network?

Human communication was manifested in many different forms at Liveweek. These included dialogue, computer communication, telephone communication, visual communication, body-language, and so on. The list could be expanded almost infinitely. By necessity, because resources were limited, my own particular study looked in depth at just a few of these forms of communication. The hope was that these few would be enough to provide a variety of "snapshots" of the communicative system that could be pieced together, hologram-like to generate an idea of the underlying communicative network structures, if any existed. The problem is, that in any complex flow-form network, ALL forms of communication contribute to the structure. This could explain why the nature of the communicative flows at Liveweek was hard to determine; I was only looking at a part of the whole system.

Nevertheless, there were elements of the communicative structure that were brought to light in my analysis that strongly suggested that there was indeed a complex flow-form network in existence. The strongest evidence in support of this was the repeat of some patterns between the datasets, and the manner in which some parts of the data sets correlated with one another. But there were also other indications that a flow-form network might have been present. For example, while there *were* boundaries within the system, these boundaries were clearly *dynamic*; as I've discussed earlier in this thesis, the boundaries within a flow-form network are *always* dynamic. At Liveweek, the teams developed distinct identities and modes of approach to their work. The way the Yellow team behaved was different from the Knowledge Capture team, and from the Green Team; this much was clear from the network analysis. However, the team identities were not finite, nor were their boundaries absolute. Team members occasionally crossed temporarily from one team to another, parts of some teams worked together on special joint projects, and resources were shared between teams.

Another element of the communicative structure that hinted at flow-form was the rapidity with which the designs emerged. Rather like a rapid-travelling fungal rhizome structure (such as the bootlaces of the honey fungus that I discussed in Chapter 6), the progress of the Liveweek teams' design activity was extremely rapid. In just two days, all of the teams produced designs that under normal construction industry conditions would have taken weeks. Moreover, the teams had considered and resolved more design problems much earlier than in a normal design; and they had done so to the greater satisfaction of those involved. In a normal construction project, fabricators and other engineers are often not brought in until quite a late stage in the design. It is at this point that new technical problems are discovered. At Liveweek however, architects, engineers, fabricators, and so on had all been brought together from the start and so had a greater *involvement* from an early stage in the project. Many of the participants said that they were much happier about the design they had co-created than in a conventionally produced project. This could well have been because they had all had an *input* from the beginning and had been given much more opportunity to voice their concerns and deal with potential problems. It could also have helped to generate the intangible positive "buzz" within the teams as they worked, which I discussed earlier in this chapter, and which made the teams' progress so exciting to watch and be involved with.

In all, I am satisfied with the outcome of this Liveweek study as it contributed to the PhD. At the outset my aim was to investigate whether, and if so how, communicative networks might develop in a human social context. Yet since the study took place at an early stage in my research, my approach to data gathering was intentionally flexible. I wanted to get as much data as I could with the methods I had knowledge of at the time. This resulted in a rich dataset which, when analysed in the light of the Inclusional framework that I had chosen to work within, gave rise to new and innovative theoretical work on the nature of communicative flow. This study therefore not only serves as a set of empirical findings that exemplify the power of the flow-form concept, but it is the original work from which the flow-form network model was developed.

Chapter 12 – Concluding Discussion

12.1 Some concluding reflections on my study

12.1.1 How does this thesis differ from my original research concept?

In this concluding chapter of my thesis, I shall begin by looking back at my aims at the outset of my research and discuss how well I think I have fulfilled them. As I discussed in Chapter 1, I started out on this study as a displaced biologist. I wanted to draw parallels between the biological systems that I knew about, and human systems about which, in academic terms, I knew very little. I wanted to conduct my study within the framework of a newly emerging research approach called Inclusionality, and within that framework I wanted to focus on issues concerning communication, systems, relationships and concepts of boundaries.

As with any new research study, I started out by finding my feet and acquainting myself with the research domain I had chosen. In my case, those early stages were a big challenge, as I'd moved into the domain of psychology, which was entirely new to me. Gradually I began to become familiar with the areas of psychology that were most relevant to my research, and the work that I have presented here does, I feel, add something new to both psychology and biology. The depth to which my study has become situated in psychology was not something that I envisaged from the start. At the outset I felt that I would be studying actual biological metaphors, rather than the philosophy and mechanism of metaphor itself, looking perhaps at what human businesses might learn from the way ant societies evolve and so on. I had a suspicion that some of the processes I was interested in might have more profound implications, but wasn't sure whether the extent of that would emerge through my study.

It was through my study of metaphor that I realised the significance that biological metaphors such as the flow-form network might have. At the outset of my study I didn't think that metaphor would play a large part in my work, as I wasn't aware of the breadth and depth of the existing literature on the subject. Later, I realised that metaphor is a thread that runs throughout my research, and consequently it features more strongly in the finished thesis than I originally supposed it would.

The inroads that I have made into Inclusionality Theory were not unanticipated. From the outset I knew that I wanted to know more about Inclusionality, but when I began my research, Alan Rayner's own development of the Inclusional approach was also in its early stages. So increasing my own understanding of the subject was no mere matter of becoming familiar with the literature. I was watching a new research perspective develop while I myself was researching its application. This was exciting. I was, however, also acutely aware that although the principles of Inclusionality Theory seemed to resonate with my own way of thinking, it was an approach that was empirically untested, had already been rejected by many in the scientific community, and because of its very novelty was unsupported by an academic precedence. I had to tread carefully. Moreover, if I was going to ground my research in such an approach, I had to be sure that I was convinced by it. Admittedly there were moments when I was very unsure, even sceptical. At times in the early stages of my study, Inclusionality seemed worryingly ethereal and elusive. Putting Inclusional ideas into words seemed to me like trying to hold a handful of sand, the harder one tried to hold onto the ideas in speech and writing, the more likely they were to slip through one's fingers.

As I progressed with my investigations, however, I found that this problem was one that lay at the heart of the conflict between Inclusionality and conventional points of view that are based on *positivistic* analysis. In a conventional paradigm, one of the hardest aspects to deal with in Inclusionality Theory is its very elusiveness. Very often Inclusionality evades words and entrapment in language. This is because much of our own language and word use is intended to be *definitive*, words are chosen for their capacity to pin down meaning and to reduce ambiguity. By contrast, in an Inclusional approach one is often dealing with concepts such as flowing space/matter relationships, permeable or ambiguous boundaries, and the need for a reduction in definition. These are very hard things to do with a language that is all about definition. I myself sometimes found (and still do) that although the Inclusional model in my head was very clear to me, I couldn't write or speak about it without sounding "fuzzy" or imprecise.

This therefore has posed a major challenge to me in writing and presenting this thesis, far more so than I imagined at the beginning of my research. I think I set out believing that the ideas in my head would somehow transform into coherent language at some stage, so I could write it all down. What I didn't envisage was the hard work it would take to achieve this transformation. I spent many long hours discussing Inclusional concepts with different people, including engineers, mathematicians, other biologists, psychologists and social scientists. In this way I tested new ways of saying things, hearing how they sounded in my head, gauging whether I was communicating the ideas effectively, and most significantly whether I believed what I was saying. This undoubtedly has helped, as the more I talked and wrote about this way of looking at things, the more I was convinced that Inclusionality was communicating something very interesting about the world, and also very new. My own study represents one of the first academic presentations of Inclusional research outside of the domain of biology, and I am very pleased to have achieved this.

As I shall discuss later in this chapter, through my study I have found that Inclusionality Theory could have significant implications not only for biology, but also for psychology. A development of models such as the flow-form network in psychology could bring Inclusionality even further towards acceptance by those involved in mainstream research. When I began my study, this certainly was not something that I had expected to find, and it is an unforeseen bonus.

12.1.2 The strengths and shortcomings of my study

In overall terms, I believe that the strengths of my own study are primarily in the theoretical work. The radical Inclusional basis of this thesis is, in my view, one of these strengths. As I've already discussed, Inclusionality is very different from conventional approaches in both biology and psychology, and as such offers a new and exciting approach to both. My own flow-form network model, which arose out of an Inclusional framework, has implications for the way that researchers from many disciplines think about process, contexts, and communication. For psychology, the flow-form network model could have significant theoretical and methodological implications; I shall discuss these in some detail later in this chapter.

Another strong aspect of this study is, I believe, how it bridges biology and psychology. As a biologist looking in on psychology I have a different perspective from those who are looking at the same topics but were "brought up in psychology". Coming into doctoral research in psychology without any previous background in the subject has been challenging, but my background in biology meant that I could consider existing psychology topics in a different way. In this thesis, I have tried to communicate to a psychology audience what it means to "think like a biologist". By learning to communicate my research in a way that engaged with psychology, I feel that I have brought insights to psychology about natural systems that might not otherwise have been readily accessible to psychologists.

The results of my empirical work are, I feel, less convincing. In some respects I feel that the empirical "Liveweek" study doesn't support my theorising as effectively as it could do. There were a number of reasons for this, but I think that it is to a large part due to the fact that the study employed only quantitative analysis, rather than qualitative. As I've explained earlier, this was probably due to my background in biology, where quantitative methods predominate, and so these were the methods with which I was most comfortable. With hindsight, perhaps I should have explored other methodologies that would have better supported my theorizing about the data, particularly where the character of the data I'd gathered seemed to be transient or intangible.

In my data analysis, I focussed on resolving whether any communicative flow had been present or absent at Liveweek, rather than on the *quality* of the flow. But by using entirely quantitative methods, I wasn't able to deduce anything about the qualities of the flows. I haven't, therefore, been able to demonstrate much about the nature of the flow, or to say what *kinds* of flow forms emerged at Liveweek. Here in a sense I have been caught by my own perceptual constraints. As a biologist, accustomed to using quantitative techniques, I have always tended to favour null hypotheses to enquire about the world, which provide clear "is it this, or is it that?" answers. In a way this is ironic, since as a result of my theoretical research I already realised that positivistic analysis methods such as the null hypothesis were unlikely to provide all the answers I was looking for. On reflection, it is possible that the quantitative approach that I have taken indicates my own preference for the lack of ambiguity that a significant quantitative result appears to provide. It also suggests however, that I too have had my own inner conflict between myself as an "analytical scientist" and as an "Inclusional enquirer"; in my empirical study, conducted at an early stage in my research, it appears that the positivistic scientist prevailed.

A final point about my empirical research is that it was perhaps somewhat uni-dimensional, as I have concentrated on analysing the *spatial* dimension of the human interactions. In the Liveweek study, I judged whether people were interacting with one another on the basis of their spatial proximity, and then I analysed their communication and environments also on the basis of where they were physically located. I didn't look specifically at how the interactions altered over time. Consequently the study has not characterised any issues of temporality or transience in the communicative flow, and these aspects have therefore been relegated to discussion without being supported by empirical results.

Given the opportunity to conduct the whole study again, there isn't a great deal that I would alter about the theoretical work. I would, however, conduct the empirical research differently. I would definitely include some kind of qualitative analysis, and I would consider time as well as space as factors in the data analysis (for example I would look at communicative flow over time as well as in spatial terms).

12.2 The nature of what I have proposed in this thesis

12.2.1 Flow-form network – ontology or epistemology?

In Chapter 1 I mentioned that there is a distinction between *models* and *metaphors*, I have developed this in Chapter 4 (section 4.3.1). To recall here, metaphor has been described as a transdisciplinary device, where one thing is thought of *as if it were* another. So, if one were to think of a business network as if it were a fungal network, one would be applying a metaphor. A model, however, can be said to be a *representation* of how things are. So if one were to use the flow-form network concept as a representation of communication patterns in a business network, one would be applying it as a model.

At various stages in this thesis I have presented the flow-form network concept as both model and metaphor, without fully resolving which I prefer. In addition to this, as I also mentioned in Chapter 1, there is a third possibility, which is to treat the flow-form concept as a form of advocacy, that is, as a *suggestion* for future practice. So, for example, if one were to approach a company and use the flow-form network concept to suggest alterations to their practice or structure, one would be using the idea to advocate change.

The issue of whether one treats the flow-form concept as metaphor, model or in advocacy is significant, because it affects our perception of what a flow-form network is. It is therefore worth discussing some of the surrounding arguments.

It might be said that in biological terms, the existence of a flow-form network is an *ontological* claim. As I've already discussed, biological flow forms are often expressed as physical structures, a fungal network being a good example, so in this case a fungal network is clearly an ontological reality. In psychology, however, ontological reality is more open to determination in multiple ways. So it might be argued that in psychology the flow-form network concept would best be treated as a model (i.e. epistemological), that is, *one* of multiple possible interpretations of psychological ontology.

When studying flow-form networks in many natural systems, however, the flow itself is not immediately obvious. This is so even in a fungal mycelial network. In a fungal network, the hyphal tubules themselves are not the communicative flow; instead they are the products of a flow process, manifested both in the growth of plastic cell wall boundaries and in the movement of protoplasmic fluid within these boundaries.

Nevertheless, in a fungal network flow-form patterns are manifested in a physically tangible manner. Because we can see the hyphal tubes, we can see where the flow is. Other biological networks are similar. Think, for example of the networks formed by herds of wildebeest as they cross the Serengeti plain, which I mentioned in Chapter 6. The collective movement of these creatures creates paths across the plain that look like flow-form networks. These trails are effectively the imprint of a flow-form network, but they are not the flow itself – the animals are, and their trails are the result of the dynamic interaction between flow and environment.

It is indeed possible that a biological network might express flow-form patterns without leaving any physical representation of the network itself. What if the wildebeest I've just described were walking over a hard surface that created no footprints? The animals would still have been expressing flow-form patterns, only without leaving a map of where they'd been.

What I am trying to demonstrate is that the absence of a physical manifestation of a flow-form network does not necessarily mean that flow does not exist in an ontological sense. For example, in many human social systems, although communicative flow might be occurring, there may be no physical manifestations of flow that are readily recognizable as network structures. Other than leaving footprints on a snowy landscape, or in the sand on a beach, we usually don't lay down physical networks according to the flow-form patterns in which we engage. Moreover, as I have suggested in my discussion of the Liveweek study, communicative flow might take the form of emotions or other insubstantial flows, such as excitement and interest, or creative ideas. I believe therefore that the flows in a human system might often actually be "intangible", rather than materially manifested.

So, in this thesis, what am I arguing for – flow-form network as metaphor, or as model? Actually I am arguing for neither, and both. This is because in the Inclusional approach that I have chosen, we don't have to resolve this issue. In an Inclusional view, all things are permeated and related with one another by space, which flows through and around every thing. Therefore, in an Inclusional approach, it does not make sense to consider one thing in isolation from all else, as such an abstraction cannot exist in reality (space can never be excluded). This does not only apply in the physical world, but also extends to epistemology and thought. No one idea, model, concept or perspective can be Inclusionally regarded in complete abstraction or isolation from its contexts. The notion of a dualistic division (such as literal/metaphor) is therefore non-evident in Inclusionality as things can exist as BOTH one thing AND another. It might sound as though I am trying to evade the issue, and not choose one approach or another, but in reality, it is by choosing *not* to choose that we can gain most. It could be argued that by not resolving which approach I am advocating, I have weakened my case for flow-form networks as a concept. However, in aligning myself with an Inclusional approach in my research, I am leaving the question open, as to resolve it one would be limiting the scope of the work in a very non-Inclusional manner.

12.2.2 Advocating flow-form networks

So, given that I've chosen not to resolve the metaphor/model issue, where might this lead us in terms of advocating the flow-form network concept? Regardless of whether we use the concept as model or metaphor, the flow-form network represents a new and radical conceptual schema. As we have seen, and illustrated with examples of networks from the natural world, flow-form networks are not constructed from discrete nodes that become connected together, rather they are formed from systems of pipes or tubes that become congruent with one another. Flow-form networks comprise flexible conduits that enable their content to flow. These flow-form networks have differentially permeable boundaries that sometimes permit their fluid contents to move into and out of the network, and at other times prevent it from crossing. The flow-form network exemplifies a structure that is flexible and adaptable, while remaining resilient; it is dynamically responsive to inner and outer contexts, and inherently communicative with both inner and outer domains.

I believe that the flow-form network concept has immense practical potential in a human organizational context. Unlike the conventional network model, wherein an organization is treated as a collection of discrete "nodes" (which may represent both people and objects) that have to be connected to one another, the flow-form concept treats an organization as an intrinsically connected system. In a flow-form network paradigm, the people are inextricable from their surroundings. Yet unlike in an extreme holistic view, where everything is related to everything else in a boundary-less homogeny, in a flow-form network boundaries are present, but they are differentially permeable. This enables features to be distinguished, while remaining inherently connected with one another. Understanding how the flow-form network model works, and how it may exist within a human organization, could bring profound insights. For example, in a healthy flow-form network, an event in one area of the network is automatically communicated to another, without any explicit action: the reciprocal flows of content and space, both around and through the interconnected pathways of the network automatically brings this about. Likewise, understanding how boundary-sealing and boundary opening might affect local responses of a network, and how these also may be communicated through the network as a whole could bring insight in a human organization; for example in a merger situation, or perhaps when responding to a computer virus attack.

At the outset of this study I asked what would happen if we were to look at a human organization as if it were a natural network. Natural networks are reflections of flow-form, so if one is to look at a human organization as if it were a natural network, one is looking to see whether it has aspects of flow-form organization. When I studied a human system in this manner (in my Liveweek study), I believe that I found some features of flow-form communication, *enmeshed* in conventional structures. As I discussed earlier, it is possible that the quantitative tools that were used to investigate the system produced a restricted picture. Indeed, I would suggest that an entire flow-form network *might* have existed at Liveweek, but the positivistic tools that were used to study it caused its full structure to remain hidden. Alternatively, the fragments of flow-form that I discovered could have been a true reflection of the communication structure. Suppose that the latter were true, it could have major implications for the way that we think about organizations. I believe that many human organizations often have unconnected fragments of flow-form networks within, but that these fragments often exist within an environment where constructed structures (which may be constructed nodal networks, or other kinds of structure, such as rigid organizational hierarchies) have been superimposed. The natural flow-forms therefore have become intertwined with artificial structures, working around and within the rigid framework that characterizes many constructed human systems.

This raises the exciting prospect that one might be able to look at any organization and find fragments of flow-forms within. One might even be able to anastomose the pathways between these fragments to create larger integrated flow-forms, which could fundamentally alter the way in which organizations communicate. I believe that application of the flow-form model is likely to be most successful where the people involved have an understanding of what flow-form actually is and what it implies. So, implementing a flow-form network metaphor will, in my view, have as much to do with bringing an understanding of the model to people, as with putting it into action.

12.3 The status of my research in the academic domain

12.3.1 What the flow-form concept might contribute to psychology

So, in view of the fact that this thesis is initially being presented to an audience of psychologists and social scientists, what specifically does it add to the existing body of knowledge in psychology? It has been suggested that that the principal news to psychologists in this thesis is the notion that *process* might be conceived of as a flow, rather than as a series of discrete events or states that become sequentially conjoined.

Allow me to illustrate this with a few brief examples. Firstly, as I explained in my discussion of models of communication in Chapter 3, the Shannon and Weaver model of information transmission is a classic example of a sequence-based model of process, where communication is treated as a sequence of state changes in the agents (or communicators) involved. In Chapter 4 (on metaphor) I have provided other examples of this discretist approach to thinking about process. Lakoff and Johnson, for example, viewed metaphor as a means of transference of concepts between one schema and another (Lakoff and Johnson, 1980). To view metaphor as a means of *transfer* between schemas, one must first treat cognitive thought itself as segmented into discrete blocks of related ideas and concepts. So the cognitive model of Lakoff and Johnson model thus assumes that thought is "packageable" into discrete schemas which become connected by metaphor. Similarly, Fauconnier and Turner's "multi domain" model of metaphor, suggests that metaphors are created when the mind superimposes one "schema map" onto another (Fauconnier and Turner, 1995). But here again, one can see that this necessarily treats cognitive processes as being distinguishable into discrete schema maps.

The division of process into discrete segments that may be connected to one another is also evident in network theory. As I have explained in some detail in Chapter 5, conventional network theory describes networks as systems of discrete nodes that become connected to one another. These nodes may represent people, organizations, or even molecules in a biological system. The connections between them represent a change in state in one manner or another, ranging from the simple "buys newspapers from", to "undergoes cellular respiration to produce". The conventional nodal network is therefore another example of discretist thinking about process.

Some might argue that a non-discretist approach to systems is already accounted for by self-organization and complexity theory, where the behaviour of a system is considered to be the result of *emergent* patterns that cannot be explained in terms of the individual alone (Holland, 1998; Cohen and Stewart, 1995). It could be argued that these approaches also account for fluid processes in a system, and as a result are akin to my own ideas on flow-form. I would argue however that in complexity theory the focus tends to remain centred on the behaviour of the *individual*, albeit in the context of whole systems. Essentially, complexity theory describes flow in terms of interaction between "agents", where any emergent fluid-like behaviour is explained by the effects of *nonlinear* interactions (see Holland, 1998).

According to Rayner (personal communication, 10th March 2006), accounting for emergence and flow in a system through nonlinearity and feedback processes is a means of accounting for what in Inclusionality theory is described as *space*. By contrast, in an Inclusional view, it is recognized that it is the presence of *space* in a system that permits flows to occur. The application of nonlinear mathematics, and of feedback processes is, according to Rayner, a way of forcing a chaotic system to account for the presence of space, and effectively "introduces space through the back door", rather than explicitly acknowledging that the space itself is an inherent factor in the system's dynamics.

Cohen and Stewart do acknowledge the need for a move away from thinking of complex systems in terms of interaction between individual parts. To quote the authors directly:

"...what we need is a theory of features, an understanding of how the geographies of spaces of the possible conspire to create new patterns and combined dynamics. Such a theory would see weather as the motion of cyclones and rain clouds, not as the motion of billions of tIny, indistinguishable particles of fluid." (Cohen and Stewart, 1995).

Unlike in a complexity theory approach, my flow-form network theory does not focus on distinguishing between individual agents. Rather it describes network flows as "streams" that are not composed of interactions between individuals, but which are patterns that emerge through the action of the continuous (and automatic) flow of space around, through and within a system.

Throughout this thesis, I have highlighted how shifting from a conventional "block-like" thinking of process and system structure towards a model based on the principles of Inclusional flow (the flow-form network) can alter our perception of a system. Suppose we were to think about psychological process not as a series of changes through various discrete states of being, but as a fluid process of transformation? Flow-form networks suggest that processes could be represented as networks of fluid and *interconnected* paths. According to the Inclusional perspective on how these networks function, these paths are *distinct* but *not separated dynamic expressions of* their context, and as such could represent process as a fluid transformation through a heterogeneous medium or environment.

Allow me to develop this idea a little further and suggest an example of how this fluid-like view of process might affect how we perceive a psychological topic; since I've already discussed it at length in this thesis, I'll use metaphor as my example. As I have explained above, Lakoff and Johnson's theory of metaphor, which is widely acknowledged as the founding basis of modern metaphor theory, is based on the idea of discrete "schemas" of thought that become connected to one another. Others, however have suggested otherwise. Chia, for example, who has studied organizations from a perspective not greatly dissimilar from my own, has presented a different view (see Chapter 4, section 4.3 for further detail). In one paper, Chia says that metaphor is a means of "de-ossifying thought"; it is a means of moving from a state where one thinks in terms of static "states", "entities" and "attributes" to one where one thinks in terms of "flux" and "transformation" (Chia 1996). According to Chia, metaphor is a means by which we can make thoughts "move". It seems to me that Chia is arguing for a model whereby metaphor is considered to be a facilitator of *flow.*

Let us consider an image of a natural flow-form network. It's evident from the photo below (Figure 12.1) that natural examples of flow-form networks can be aesthetically beautiful. Another illustration would be the video I have seen of a fungal mycelial network photographed at intervals during its development and replayed at speed, the flow-patterns that emerge are elegant and fascinating to watch.

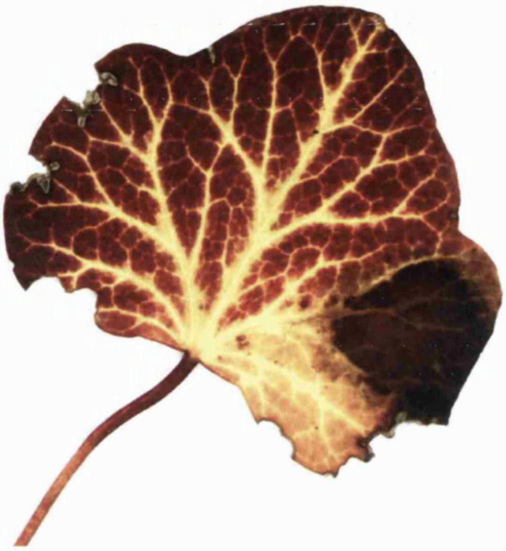


Figure 12.1 Venation pattern on an ivy leaf (*Hedera helix*) in autumn.

Flowing visual patterns such as this appeal to the pattern-loving sense of our minds. When images of natural flow-form patterns are presented as a metaphor for human organizational structure, they can provoke new and exciting organizational insights. In essence, the visual representations of natural flow-form networks are themselves acting as facilitators of flow of understanding and insight. Perhaps, as well as being a metaphor in its own right, the flow-form network model might actually begin to explain how metaphorical thought works. Might it be that the communicating effect of metaphors *between* and *through* different topic domains is actually an indication of flow-form? Metaphor communicates within and between shared domain spaces. So one might surmise that, the flow-form network is both metaphor *itself*, and a *model* of how metaphors might work.

I am not alone in suggesting such a view. In a recent paper on metaphor Abrams wrote: "Mind like water shifts and flows, and is not fragmented. Ideas are not "linked together" at a given stable point remaining largely separate from one another. Ideas are not like links in a chain at all - not self-contained but attached - but are fused with one another, some more, some less intensely." (Abrams, 2002). Abrams went on to suggest that metaphor arises out of this fluidity of cognition, rather than by connections being made between distinct schemas of thought.

12.3.2 How this thesis contributes to the debate on tools and methodologies in the social and natural sciences

As I have demonstrated and discussed throughout this thesis, most conventional positivistic tools are not suited to the study of flow-form networks. These tools, which often work by breaking a system down into smaller parts, tend to disrupt any flow processes that exist within it. Moreover, many conventional methods of analysis disagree at a fundamental level with an Inclusional perspective, since they tend to excise parts of a system from their contexts, and to ignore the manner in which the common medium of space creates implicit relationships between every thing. If we are to pursue further research into flow-form networks, there is therefore a need to develop novel methods, or alternative ways of using conventional methods to reveal and characterize flow-form structures.

In terms of my own empirical research, in the Teamwork study I chose to use existing quantitative analytical tools, but I attempted to use them in a manner that I believed would minimize their limitations in a system where I suspected flow-forms might be present. I do think that this worked, but only to a limited extent. As I have discussed earlier in this chapter, the outcome was somewhat ambiguous, and although I felt that there were indications that some kind of flow-form might be emerging, the methods I had used were unable to characterize the flow. I was left with an uneasy feeling that the patterns that I had found might have been merely artifacts, or illusions generated by the analysis process itself, while the real nature of the system remained elusive and unexplored.

The methods I chose to use at Liveweek were primarily quantitative rather than qualitative. I felt that choosing quantitative methods would enable numerical or statistical patterns, if there were any in the system, to be more readily distinguished than through qualitative analysis. The problem however, was that these tools proved to be very limited where the patterns within the system were less than distinct. In these circumstances I was trying to use the quantitative methodologies to entrap intangible aspects of human communication patterns, which as I've found, is something that they are not very good at. The essence of things that are intangible is that they elude one's grasp. But the purpose of many quantitative tools is to highlight the patterns that are well defined, lifting them out from the noise of their "background" contexts so that we might see them more distinctly. Clearly then, the two are incompatible.

My Liveweek study suggested that as well as being intangible, the communicative medium in a human flow-form network might also be *transient* or inconstant. Sometimes flow-forms might be strongly expressed, at other times they may be reduced or unapparent. This dynamic, inconstant nature of the flow means that it is not ideally suited to the "snap-shot" type analysis that is essential to most quantitative research methodologies. Unlike the transactional relationships in a nodal network, which could be recorded as instances or occurrences that may be marked as a line between nodes on the network map, these transient flow-forms would need some kind of dynamic analysis to characterize them properly. To use an analogy, when standing by a river, one may see the water passing and recognized it as flow. One may also catch a little of the water in a cup and study it (which is essentially what I was doing with the communicative flow in my dialogue analysis), but this doesn't necessarily tell one about the *dynamics* of flow that are created within the system. Physicists and engineers have developed methods for studying the dynamics of fluid flow (Moran and Shapiro, 1992); now the challenge in the domain of flow-form networks is to develop methods for studying dynamic human communicative flow.

In broader terms my thesis has, I feel, highlighted the considerable conceptual and methodological differences between biology and psychology, and the flow-form concept may have significant implications for how we conceive of both social and biological systems. As Robson (2002) points out, many methodological approaches in the social sciences are quite different from those in the biological sciences. In the biological sciences most researchers seek to create theories by rigorous observation or investigation of real-world phenomena; these theories may then be applied in real world contexts. Robson argues that the approach in the social sciences can be quite different, as here theories are often *developed* through their application in real world contexts. According to Robson, perspectives that recognize that there is an active and symbiotic link between researcher and researched are becoming increasingly common in the social sciences. In approaches such as action research, says Robson, there is a genuine exchange of knowledge between researcher and researched, which is quite different from lab-based experiments.

This kind of approach, where the researchers themselves are believed to be part of the system that they are researching, is seen very rarely in the natural sciences. By contrast, in the natural sciences it is much more common to make a clear distinction between the researcher and the subject of research. Here, it is not unusual to refer overtly to "reducing experimenter effects" (e.g. Field and Hole, 2003), and natural scientists often cite the need for the experiment to be reproducible by any other scientist as the reason for this (Porush, 1995).

It is my view that Inclusionality, and my flow-form model in particular bring further depth to "active" research methodologies. They represent a framework that explains and gives depth to the relationships between researcher and researched, situating and connecting them in terms of spatial flow processes, rather than expressing the relationship between researcher and research subject as one of detachment, or entirely independent observation.

12.3.3 Potential methodologies to use in further research on flow-form

How then might we study flow-form networks in future research? I approached this study wanting to use several different methods to investigate the communicative flows within the Liveweek event. In the end I used mostly quantitative methods, which as I've just discussed, caused problems. For future research of the flow-form network concept, I still feel that an approach that combines quantitative and qualitative methodologies is a good one, but there is a need to develop the qualitative side further. Qualitative techniques should enable us to characterize the *nature* of the flow, rather than to work out simply whether it does or does not exist.

In practical terms, there are various ways we could use qualitative methods to bring the character of flow in a flow-form network to light. In a human system such as Liveweek, it would be relatively easy to do this, as we could ask the participants themselves about the system that they were acting within. The aim would be to find whether, and if so how, they think of themselves within the system, and whether the notion of flow resonates with them or not. We could for example ask them about what they think about themselves relative to any "upward and downward streams" in the system. Asking about the participants' perceptions of their *contexts* would also be important, as this could give an indication of the way in which they perceive the boundaries between themselves and their environments (i.e. the boundary between their inner and outer contexts). I think that it would be of use to employ the Inclusional language of space, inner and outer contexts and so on, to see whether they resonate more with some people, and less with others. We could ask the members of a system or organization to imagine that flows might exist in what they and their organization do, and then ask them what they think the flow is like – is the flow rapid and smooth, or do they perceive any blockages to flow in the system? We could also enquire about people's attitudes over *time*; do they change, are they static? From all these qualitative data, it might even be possible to create a "map" or some other representation of the subjective perceptions of flow within a system.

As I mentioned a moment ago, despite the problems associated with quantitative analysis of flow, I feel that quantitative methods could still be used to analyze flow-form. Unlike in my Liveweek study however, where the quantitative methods were used to find whether or not flow was present, in future work I would shift the focus to finding *levels* of flow. In a human system this could be achieved in various ways. For example, in an online environment, we could count how many people visit a web site, before tracking the path that they take onwards from that site (this would be fairly easy to do from a technical IT perspective). It would also be interesting to introduce some kind of temporality to this quantitative analysis. One possibility would be to somehow map any tangible (and visible) flows over time. I have found a way of doing this (unfortunately after the Liveweek event, or I would have tried it there), using a camera with infrared film. One could set up a camera at some suitable vantage point over a collection of people, such as those at Liveweek, or perhaps some other communal situation, such as a train station or a supermarket. Leaving the infrared camera on a single exposure for a length of time would catch the movement of people as "trails" on the image, showing the collective flow patterns that they have created.

We could employ techniques such as this, which make visible representations of actual flow patterns, in combination with qualitative studies of the perceptions and attitudes of the people within the system. In this way we would end up with a set of results that tangibly indicates or *evokes* the patterns of a human flow form network, which also characterizes the *nature* of the flow in greater detail.

12.3.4 Possible research programmes which might follow from the adoption of the flow-form network model

So where might the research presented in this thesis lead to next? There are a few immediate projects that come to mind that develop the Liveweek study. There is also, I feel, the exciting prospect of developing the flow-form network concept in a wider research programme, which might begin in psychology, but could equally be adopted in other domains. In the following section I shall present some of my thoughts on the specific areas first, before moving on to discuss some more generic research and application ideas that emerge from this study.

12.3.4.1 Projects that expand on the Liveweek study

After the Liveweek event, the organizers were keen to apply some of the collaborative work concepts in a "real-life" construction design situation; they wanted to use "Teamwork" principles on a live construction project. Sadly, although the idea was discussed in some depth, the project didn't progress any further than the planning stage as it became blocked at many stages by apparently insurmountable practical and contractual issues. Nevertheless, I feel that the messages that emerged from Teamwork could, with further investigation, be applied in a real-life organizational situation. Firstly, however, I believe that further research needs to be conducted in real-life contexts, with particular emphasis on the nature of networks, and flow-form communication in such situations. To be able to apply the new ideas that emerged from Liveweek, one would need first to find out the nature of the differences between the Liveweek situation and real-life collaborative design projects that are run along conventional lines. One way of doing this would be to conduct a study on a real-life collaborative design project, which used a similar set-up to my Liveweek study, but that ran over a much longer period. One could use similar multi-method techniques to identify patterns of communication within and between the organizations and people involved, co-ordinating the results to gain insight into the communicative flow patterns within.

12.3.4.2 Investigating the role of IT in generating and supporting flow-form communication patterns

Another area where I believe the flow-form network concept could have immediate impact is in the study of computer-mediated communication. As I noted in Chapter 11, computer technology played a key communicative role in the collaborative design process at Liveweek. Currently, in most conventional construction projects, teams of designers from different companies are not physically co-located for the duration of the project. They therefore rely heavily on a variety of distance-spanning modes of communication, which includes telephone and computer-mediated communication. It would be interesting to investigate how computers are used in conventional business situations, to include the extent to which they act as communicative tools, whether this differs from the way in which computers were used at Liveweek, and significantly, whether computer technology acts as a means of facilitating flow-form patterns in such an environment.

This leads me to suggest another, more general avenue for research into flow-form networks. It would be of interest to learn the extent to which IT may be used as a tool to support and generate flow-form communication patterns in human systems. During Liveweek, the team members clearly used IT as a means of communicating information between different disciplines, as well as between different cultures, languages, skill levels and communicative styles. I feel that it is entirely possible that, like metaphor, IT could be considered as a tool that facilitates flow-form communication. Research on this topic would need to be conducted in an Inclusional fashion that considers not only IT as a tool, but also the contextual situations in which it is used, to include physical environments, human social and communicative contexts and so on.

12.3.4.3 Other research possibilities, in psychology and elsewhere

It is not difficult to think of other arenas where a model of flow-form interaction might be useful. Some that come to mind include human flow patterns in crowds and other social groupings (such as the railway station and supermarket contexts that I have already mentioned, to a wider business/organizational context, which might include logistics, supply chain management and so on. One might also see the potential of this kind of thinking if it were applied to communications in security operations, intelligence, or research into terrorist behaviour.

In contrast to conventional network theory however, I choose not to propose here that flow-form networks might be condensed into a model (mathematical or otherwise) that might be *proven* to exist in all these domains. Rather, I am suggesting that thinking of the processes within and around these human systems as fluid-like behaviours may bring light to some of the ontological features that we may observe. The flow-form concept has, I believe, much potential as a *way of thinking* about social systems and human behaviour. Its representation of *process* as a flowing dynamic feature of a system offers a new and different perspective within the holographic reality of the social sciences, and as such, its potential is very wide indeed.

12.4 What has been proposed in this thesis about the relationship between Inclusionality theory and psychology

In this penultimate section of this chapter, I would like to clarify what the philosophical framework of Inclusionality (on which I have based so much of my theorizing), might add to the domain of psychology.

In one sense, I have used Inclusionality theory in this thesis as a conceptual bridge between biology and psychology, as a transdisciplinary tool perhaps. Others have created similar connections between our understandings of inner psychological and outer corporeal and social worlds. For example, Harré (2002) wrote about an integrated "scientific psychology" where the psychological (P) is situated within the context of a human organism (O), and which is inherently related to the molecular functioning of the brain and body (M). Harré said it was not possible to understand the psychological in isolation, because all human activity is grounded in and enabled by bodily processes and neural activity.

Cromby (2004) develops on this idea and suggests that one might connect social constructionist theory with neuroscience. According to Cromby, it is not correct to look at these two subjects in a dualistic sense, rather they are inherently connected, just as Harré suggested with the inner psychological and the corporeal. Cromby suggests the relationship between the social self and the embodied self (i.e. physical/neurological) is transformative (i.e. they transform one another), and that their co-created trajectories also shape future actions. Cromby points out that the interpersonal self (the embodied psychological self) is always situated within *society*. This is a spatio-temporal situatedness that contextualizes the interpersonal self within history and culture of a society, as well as in day-to-day interactions.

I believe that Inclusionality theory could be important to psychology, as it is a framing that enables us to understand this kind of *interconnectedness*. The Inclusional approach has some resonance with approaches to social science that permit a plurality of viewpoints to co-exist. But it also presents an *explanation* for why the co-existence of multiple perspectives can work. Inclusionality theory explains that all things are inherently connected as a consequence of the fluid permeation of *space* throughout our worlds, inner outer and universal. According to Inclusionality, ontological and epistemological worlds intermingle and co-exist with one another. That which is corporeal, explicit, material or tangible is inextricable from that which is non-material, space, intangible or implicit. Significantly, the Inclusional view does not create a holistic homogeneity, since the presence of dynamic boundaries enables unique identities to be sustained. It is these boundaries that relate forms with their worlds, both inner and outer, but they also distinguish one thing from another.

Inclusionality theory also suggests something important about the theory of methodologies used to enquire about a system. In an Inclusional approach, alternative points of view are considered to be necessary because it is the very differences between them that create *meaning*. It is the dynamic interplay between varying points of view that creates distinction and identity. In an Inclusional view, the world expresses itself through varying degrees of concurrence and dissonance between inner and outer contexts, and it is by studying these relationships that we can begin to understand it.

What is perhaps most exciting about the Inclusional model for psychology is that it perceives social and psychological processes as *fluid* transformations. Our social existences are not purely the result of explicit action between people, or of transactional dialogues or discourse. Rather, they are the result of fluid interactions between inner and outer contexts. The flow-form network model serves as an illustration of this, but it is the Inclusional principles that give it grounding.

12.5 A concluding statement on my own intellectual journey through this research

To conclude, I will summarize my thoughts on the journey that I have made through my doctoral research study and in preparing this thesis. I started out on this research as a biological scientist. I was trained in the methods of scientific analysis, which I knew well and liked using. As a result of my contact with Inclusionality theory, I also had an idea that in questioning the manner in which we might investigate natural systems, we might also reveal things about human systems. The interdisciplinary nature of what I proposed to study meant that I could ground my study either in the natural sciences, or in psychology. Since I encountered more cooperation and interest in psychology than in biology, it was there that I registered my study. At the outset however, I had very little knowledge of any kind of psychology, so the work that I have presented here is also an account of what I have learned about psychology, and particularly of critical approaches to psychology. I am at heart still a biologist, but now I do at least feel that I know enough about the relevant aspects of psychology and social science to demonstrate what my research might mean to the domain of psychology.

I have also considerably developed my understanding of Inclusionality theory. I have watched the theory itself being developed by Alan Rayner and others, and I have myself contributed something new and relevant in the form of my work on flow-form networks.

I have discovered that methodology is very important in research of this kind. My empirical study took place at a relatively early stage in my research process, and the bulk of my theorizing therefore happened afterwards. I approached the empirical study from the perspective of an "observer" and tried to implement quantitative analysis techniques to capture some of the intangible flows within a human system. I have subsequently realized that there are other ways of doing this that might be more successful, and now believe that an approach that incorporates qualitative techniques as well as quantitative ones would have been more appropriate.

I intend to continue researching along these lines in the future. I would like to develop on Inclusional perspectives of communicative flow, and particularly on ways of analyzing and communicating these perspectives. I feel that there is considerable scope to do this, both within the domains of psychology and in other areas, and perhaps even to develop a novel interdisciplinary programme of research on the subject.

References

Abrams, J.J. (2002), Philosophy after the mirror of nature: Rorty, Dewey, and Peirce on pragmatism and metaphor. *Metaphor and Symbol*, 17:227-242.

Ackroyd, S. and Hughes, J. (1992), *Data collection in context.* Second edition. Harlow: Longman.

Ainsworth, A.M., Beeching, J.R, Broxholme, S.J., Hunt, B.,A, Rayner, A.D.M. and Scard, P.T. (1992), Complex outcome of reciprocal exchange of nuclear DNA between two members of the basidiomycete genus Stereum. *Journal of General Microbiology*, 138:1147-1157.

Albert, R., Jeong, H and Barabasi, A.L. (2000), Error and attack tolerance of complex networks. *Nature*, 406:378-382.

Albert, R., Jeong, H. and Barabasi, A.L. (1999), Diameter of the world-wide web. *Nature*, 401:130-131.

Alberts, B., Bray, D., Lewis, J., Raff, M., Roberts, K. and Watson, J.D. (1994), *Molecular biology of the cell*, (third edition). New York: Garland.

Albritton, D.W. (1995), When metaphors function as schemas: some cognitive effects of conceptual metaphors. *Metaphor and Symbolic Activity*, 10:33-46.

Aouad, G., Kagioglou, M., Cooper, R., Hinks, J. and Sexton, M. (1999), Technology management of IT in construction: a driver or an enabler? *Logistics Information Management*, 1:130-137.

Arenas, A., Danon, L.,Diaz-Guilera, A., Gleiser, P.M. and Guinera, R. (2003), Community analysis in social networks. *European Physics Journal,* 2003.

Aristotle. *Rhetoric. Book III.* Trans. W. Rhys Roberts. E-book version, Adelaide, (2004). http://etext.library.adelaide.edu.au/a/aristotle/a8rh/

Atlan, H. and Cohen, I.R. (1998), Immune information, self organization and meaning. *International Immunology*, 10:711-717

Austin, S. and Steele, J. (2001), Mapping the conceptual design activity of interdisciplinary teams. *Design Studies*, 3:211-232.

Aviv, R., Erlich, Z. and Ravid, G. (2003), *Cohesion and roles: network analysis of CSCL communities*. Paper given at the 3rd IEEE International Conference on Advanced Learning Technologies, Athens, Greece, 9th-11th June 2003.

Ball, P. (1999), *The Self-made Tapestry*. Oxford: Oxford University Press.

Barabasi, A. L.. (2003), *Linked*. New York: Plume.

Baron, S.W. and Tindall, D.B. (1993), Network structure and delinquent attitudes within a juvenile gang. *Social Networks*, 15:255-273.

Baskin, K. (1998), *Corporate DNA*. Woburn, Massachusetts: Butterworth Heineman.

Bateson, G. (1972), *Steps to an ecology of mind*. Reprinted 2000, Chicago: University of Chicago Press.

Battram, A. (1998), *Navigating Complexity*. London: The Industrial Society.

Berlow, E. L., A.-M. Neutel, J. E. Cohen, P. De Ruiter, B. Ebenman, M. Emmerson, J. W. Fox, V. A. A. Jansen, J. I. Jones, G. D. Kokkoris, D. O. Logofet, A. J. McKane, J. Montoya, and O. L. Petchey. (2004), Interaction strengths in food webs: Issues and opportunities. *Journal of Animal Ecology*, 73:585-598.

von Bertalanffy, L. (1968), *General system theory*. New York: George Braziller.

Bien, W., Marbach, J. and Neyer, F. (1991), Using egocentred networks in survey research. A methodological preview of an application of social network analysis in the area of family research. *Social Networks*, 13:75-90.

Blasko, D.G. (1999), Only the tip of the iceberg: Who understands what about metaphor? *Journal of Pragmatics*, 31:1675-1683

Bohm, D. and Peat, F. D. (1987), *Science, order and creativity*. New York: Bantam.

Boddy. L., Wells, J.M., Culshaw, C. and Donnelly, D.P. (1999), Fractal analysis in studies of mycelium in soil. *Geoderma*, 88:301-328.

Boots, M. and Sasaki, A. (1999), “Small worlds” and the evolution of virulence: infection occurs locally and at a distance. *Proc. Roy. Soc. London*, 266:1933-1938.

Borgatti, S.P. (2002), *Netdraw for Windows*. Harvard: Analytic Technologies.

Borgatti, S.P., Everett, M.G. and Freeman, L.C. (2002), *Ucinet for Windows: Software for Social Network Analysis*. Harvard: Analytic Technologies.

Borgatti, S.P. and Foster, P.C. (2003), The network paradigm in organizational research. *Journal of Management*, 29:991-1013.

Borovoy, R., Martin, F., Resnick, M. and Mcdonald, M. (1997), *Designing Groupwear: weaving silicon webs into the social fabric.*
http://lcs.www.media.mit.edu/groups/el/projects/tag/groupwear.pdf

Borovoy, R., McDonald, M., Martin, F., and Resnick, M. (1996), Things that blink: computationally augmented nametags. *IBM Systems Journal*, 35:488-495.

Brandes, U. and Carman, S.R. (2003), Visual unrolling of network evolution and the analysis of dynamic discourse. *Information Vizualisation*, 2:40-50.

Broekstra, G. (1996), The triune-brain metaphor: the evolution of the living organization. In D. Grant and C. Oswick, (eds.), *Metaphor and Organizations*, London: Sage.

Buchanan, M. (2003), *Small world*. London: Phoenix.

Budd, J.M. and Raber, D. (1996), Discourse analysis: Method and application in the study of information. *Information Processing and Management*, 32:217-226.

Bull, P. (2002), *Communication Under the Microscope.* Hove: Routledge.

Burch, H. and Cheswick, B. (1997), *The Internet Mapping Project.*
http://research.lumeta.com/ches/map/

Callaway, D.S., Newman, M.E.S, Strogatz, S.H. and Watts, D.J. (2000), Network robustness and fragility: percolation on random graphs. *Physical Review Letters*, 85:5468-5471.

Cambel, A.B. (1993), *Applied chaos theory*. London: Academic Press.

Cancho, R.F. and Sole, R.V. (2001), The small-world of human language. *Proc. Roy. Soc. B,* 268:2261-2266.

Capra, F. (2003), *The Hidden Connections*. London: Harper Collins.

Capra, F. (1996), *The Web of Life.* London: Harper Collins.

Capra, F. (1982), *The Turning Point*. New York: Simon and Schuster,

Capra, F. (1976), *The Tao of Physics.* London: Fontana.

Carmeliet, P. (2004), Manipulating angiogenesis in medicine. *Journal of Internal Medicine*, 255:538-561.

Cartwright, D. and Harary, F. (1956), Structural balance: a generalisation of Heider's theory. Psychological Review, 63:277-293.

Chen, L.L.J. (1997), Modeling the Internet as cyberorganism: a living systems framework and investigative methodologies for virtual cooperative interaction. Unpublished Ph.D. Thesis, University of Calgary. (Available at http://citeseer.ist.psu.edu/179078.html).

Cheng, E.W.L, Li, H., Love, P.E.D. and Trani, Z. (2001), Network communication in the construction industry. *Corporate Communications*, 6:61-70.

Chi, M. T. H. (1997), Quantifying qualitative analyses of verbal data: a practical guide. *The Journal of the Learning Sciences*, 6:271-315.

Chia, R. (1996), Metaphors and metaphorization in organizational analysis: thinking beyond the thinkable. In D. Grant and C. Oswick, (eds.), *Metaphor and Organizations*, London: Sage.

Choudhury, T., and Pentland, A. (2003), Modeling face-to-face communication using the sociometer. Proceedings of the International Conference on Ubiquitous Computing, Seattle, WA. October 2003. (http://web.media.mit.edu/~tanzeem/shortcuts/

Clark, H.H. and Brennan S.E. (1991), Grounding in communication. In L.B. Resnick, J.M. Levine and S.D. Teasley (eds.), *Perspective on socially shared cognition.* Washington, DC: American Psychological Association.

Cobley, P. (ed.) (1996), *The Communication Theory Reader.* New York: Routledge.

Cohan, S. and Shires, L.M. (1996), Linguistic Value. In *The Communication Theory Reader*, P. Cobley (ed.). New York: Routledge.

Cohen, J. and Stewart, I. (1995), *The Collapse of Chaos.* London: Penguin.

Conway, S., Jones, O. and Steward, F. (2001), Realising the potential of the network ``perspective in innovation studies. In O. Jones, S. Conway & F. Steward, (eds.), *Social Interaction and Organizational Change: Aston Perspectives on Innovation Networks*, London: Imperial College Press.

Corner, L.A.L., Pfeiffer, D.U. and Morris, R.S. (2003), Social network analysis of Mycobacterium bovis transmission among captive brushtail possums (*Trichosurus vulpecula*). *Preventive Veterinary Medicine*, 59:147-167.

Cromby, J., Between constructionism and neuroscience. The societal co-constitution of embodied subjectivity. *Theory and Psychology*, 14:797-821.

Csikzentmihalyi, M. (1992), *Flow: the Psychology of Happiness.* London: Rider.

Dawkins, R. (1986), *The Blind Watchmaker.* Oxford: Oxford University Press.

Dawkins, R. (1982), *The Extended Phenotype.* Oxford: Oxford University Press.

Dawkins, R. (1976), *The Selfish Gene.* Oxford: Oxford University Press.

van Dijk, T. A. (1997), The Study of Discourse. In T.A. van Dijk, (ed.), *Discourse as Structure and Process*, London: Sage.

Dooley, K.J., Corman, S.R. and McPhee, R.D. (2003), Modelling high-resolution broadband discourse in complex adaptive systems. *Nonlinear Dynamics, Psychology, and Life Sciences*, 7:61-85.

Dunne, J. A., Williams, R.J. and Martinez, N.D. (2002), Food web structure and network theory: the role of connectance. *Proceedings of the National Academy of Science, USA*, 99:12917-12922

Eliasmith, C. (1998), The third contender: a critical examination of the dynamicist theory of cognitions. In P. Thagard, (ed.) *Mind readings*, Cambridge, MA: MIT Press.

Fairholm, F.R. (2004), A new sciences outline for leadership development. *The leadership and organization development journal*, 25:369-383.

Family, F., Masters. B.R. and Platt, D.E. (1989), Fractal pattern formation in human retinal vessels. *Physica D* 38:98.

Fauconnier, G. (1997), *Mappings in Thought and Language.* Cambridge: Cambridge University Press.

Fauconnier, G. and Turner, M. (1995), Conceptual integration and formal expression. *Journal of Metaphor and Symbolic Activity*, 10:183-203.

Faust, K. and Skvoretz, J. (2002), Comparing networks across space and time, size and species. *Sociological Methodology*, 2002:267-299.

Field, A. and Hole, G. (2003), *How to design and report experiments.* London:Sage.

Gabor, S. and Csabai, I. (2002), The analogies of highway and computer network traffic. *Physica A,* 307:516-526.

Gates, B. (1999), Business at the speed of thought. *Business Strategy Review*, 10:11-18.

De Geus, A. (1997), *The Living Company.* London: Nicholas Brealey.

Gleick, J. (1987), *Chaos*. London: Abacus.

Gomm, R. (2004), *Social research methodology.* Basingstoke: Palgrave Macmillan.

Goodwin, B. (1997), *How the Leopard Changed its Spots.* London: Phoenix.

Grady, J. E., Oakley, T. and Coulson, S. (1999), Blending and metaphor. In G. Steen & R. Gibbs (eds.), *Metaphor in Cognitive Linguistics*, Philadelphia: John Benjamins.

Granovetter, M. (1973), The Strength of Weak Ties. *American Journal of Sociology*, 78:1360-1380.

Greenfield, S. (1995), *Journey to the Centers of the Mind.* New York: Freeman.

Guare, J. (1990), *Six Degrees of Separation: a Play.* New York: Vintage Books.

Harré, R. (2002), *Cognitive Science, a philosophical introduction.* London:Sage.

Haste, H. (2000), Challenging dualism: sexual metaphors and changing models of science and rationality. In H. Ajroud (ed.), *Dualities.* University of Tunis Press.

Haste, H. (1993), *The Sexual Metaphor.* Cambridge, Massachusetts: Harvard University Press.

Hawksworth, D. L. (1991), The fungal dimension of biodiversity: magnitude, significance, and conservation. *Mycological Research,* 95:641-655.

Heylighen, F. and Bollen, J. (1996), The World-Wide Web as a Super-Brain: from metaphor to model. In R. Trappl (ed.), *Cybernetics and Systems '96*, Austrian Society for Cybernetic Studies.

Hill, R. C. and Levenhagen, M. (1995), Metaphors and mental models: sensemaking and sensegiving in innovative and entrepreneurial activities. *Journal of Management*, 21:1057-1073.

Holland, J.H. (1998), *Emergence.* Oxford: Oxford University Press.

Huberman, B.A. and Adamic, L.A. (2003), Information dynamics in a networked world. In E. Ben-Naim, H. Frauenfelder and Z Torocskai (eds.), *Lecture Notes in Physics, Volume 650: Complex Networks.* New York: Springer.

Husbands, P. (1994), Genetic Algorithms for Scheduling, *AISB Quarterly*, 89. Also at: http://citeseer.ist.psu.edu/149983.html

Jack, A. (2004), *Red Herrings and White Elephants*; *the Origins of the Phrases We Use Every Day*. London: Metro.

Jeong, H., Tombor, B., Albert, R., Oltvai, Z.N and Barabasi, A. L. (2000), The large-scale organization of metabolic networks. *Nature*, 407:651-654.

Jones, C. (2004), Networks and learning: communities, practices and the metaphor of networks. *Alt.-J*, 12:81-93.

Judge, A. (1991), Metaphors as transdisciplinary vehicles of the future. Paper for the Conference on Science and Tradition: Transdisciplinary Perspectives on the way to the 21st Century, Paris, December 1991.

Karathanos, K.H. (1994), Communication network analysis and dysfunctional organizational coalition. *Management Decision*, 32:15-19.

Kauffman, S. (1995), *At Home in the Universe*. Oxford: Oxford University Press.

de Laat, M. (2002), Network and content analysis in an online community discourse. Paper presented at the Networked Learning Conference, Sheffield, 2002.

Lakoff, G. (1992), The Contemporary Theory of Metaphor. In A. Ortony, *Metaphor and Thought* (2nd edition), Cambridge: Cambridge University Press.

Lakoff, G., and Johnson, M. (1980), *Metaphors We Live By*. Chicago: The University of Chicago Press.

Laszlo, E. (1996), *The Systems View of the World*. New Jersey: Hampton Press.

Lewin, R. and Regine, B. (1999), *The Soul at Work*. London: Orion.

Liljeros, F., Edling, C.R., Nunes Amaral, L.A., Stanley, H. E. and Aberg, Y. (2001), The web of human sexual contacts. *Nature*, 411:907-908.

Lipponen, L., Rahikainen, M., Lallimo, J. and Hakkarainen, K. (2003), Patterns of participation in discourse in elementary students' computer-supported collaborative learning. *Learning and Instruction*, 13:487-509.

Lissack, M.R. (1997), Of chaos and complexity: managerial insights from a new science. *Management Decision*, 35:205-218.

Littlejohn, S. W. (2002), *Theories of Human Communication*. California: Wadsworth.

Loosemore, M. (1998), Social network analysis: using a quantitative tool to explore the management of construction crises. *Int. J. Project Management*, 16:139-144.

Lovelock, J.E. (1979), *Gaia*. Oxford: Oxford University Press.

Lovelock, J. and Margulis, L. (1997), The Gaia hypothesis. In L. Margulis and D. Sagan, (eds.), *Slanted Truths*, New York: Copernicus.

Mandelbrot, B. B. (1983), *The Fractal Geometry of Nature*. New York: Freeman.

Mangham, I.L. (1996), Some consequences of taking Gareth Morgan seriously. In D. Grant and C. Oswick, (eds.), *Metaphor and Organizations*, London: Sage.

Marsh, L. and Flanagan, R. (2000), Measuring the costs and benefits of information technology in construction. *Engineering Construction and Architectural Management*, 7:423-435.

McCarthy, J.F., Costa, T.J., and Liongosari, E.S. (2001), UniCast, OutCast and GroupCast: an exploration of new interaction paradigms for ubiquitous, peripheral displays. Proceedings of CHI 2001, Workshop on Distributed and Disappearing User Interfaces in Ubiquitous Computing, ACM Press.

McCarthy, J.F. and Meidel, E.S. (1999), ACTIVEMAP: a visualization tool for location awareness to support informal interactions. In H. W. Gellersen, (ed.), *Handheld and Ubiquitous Computing. Proceedings of the International Symposium (HUC '99),* Karlsruhe, Germany, September 1999.

McDougall, S.R., Anderson, A.R.A., Chaplain, M.A.J. and Sheratt, J.A. (2002), Mathematical modelling of flow through vascular networks: implications for tumourinduced angiogenesis and chemotherapy strategies. *Bulletin of Mathematical Biology*, 64:673-702.

McGregor, S. L. T. (2004), The nature of transdisiplinary research and practice. http://www.kon.org/hswp/archive/transdiscipl.pdf

Medway, P. and Clark, B. (2003), Imagining the building: architectural design as semiotic construction. *Design Studies*, 24:255-273.

Milgram, S. (1967), The small world problem. *Psychology Today*, 2:60-67.

Miliata, K. (1997), The persistence of emergence. In R. A. Eve, S. Horsfal and M.E. Leed, (eds.), *Chaos, complexity and sociology*, California: Sage.

Moran, M.J. and Shapiro, H. N. (1992), *Fundamentals of Engineering Thermodynamics*, New York: Wiley.

Morgan, G. (1996), *Images of organization.* 2nd Ed., London: Sage.

Murray, P.J. and Robson, W. (2002), Metaphor and worldview. Paper presented at the BEST conference "Supporting the teacher: challenging the learner." Edinburgh 8-10 April, 2002.

Nardi, B.A. and O'Day, V.L. (1999), *Information Ecologies.* Cambridge, MA: MIT Press.

Newman, M. E. J. (2001), The structure of scientific collaboration networks. *Proceedings of the National Academy of Science, USA*, 98:404-409.

Olkkonen, R., Tikannen, H. and Alajoutsikarvi, K. (2000), The role of communication in business relationships and networks. *Management Decision*, 6:403-409.

Ortony, A. (1998), *Metaphor and Thought.* Second edition. Cambridge: Cambridge University Press.

Osgood, C.E., Suci, G.J and Tannenbaum, P.H. (1957), *The Measurement of Meaning.* Urbana: University of Illinois Press.

Paine, R.T. (1966), Food web complexity and species diversity. *American Naturalist,* 100:65-75.

Palmer, J. (1998), The human organization. *Journal of Knowledge Management*, 1:294-307.

Paolillo, J.C. (1999), The virtual speech community: social network and language variation on IRC, 32nd Int. Hawaii Conference on Systems Science.

Papakyriasis, N.V. and Boudourides, M.A. (2001), Electronic weak ties in organizations. Paper presented at the 4th GOR Conference, Goettingen, Germany, May 17-18, 2001.

Pavlovich, K. (2003), All that jazz. *Long Range Planning,* 36:441-458.

Pelletier, J.D. and Turcotte, D.L. (2000), Shapes of river networks and leaves: are they statistically similar? *Phil. Trans. R. Soc. Lond. B,* 355:307-311.

Penrose, R. (1999), *The Emperor's New Mind*, (second edition). Oxford: Oxford University Press.

Perry, M. and Sanderson, D. (1998), Coordinating joint design work: the role of communication and artefacts. *Design Studies*, 19:273-288.

Petrie, H.G. and Oslag, R.S. (1993), Metaphor and learning. In A. Ortony (ed). Second edition, Metaphor and Thought, Cambridge: Cambridge University Press.

Pimm, S.L. (1980), Food web design and the effect of species deletion. *Oikos*, 35:139-149.

Porush, D. (1994), *A short guide to writing about science.* New York: Harper Collins.

Pratchett, T. (1992), *Reaper Man.* London: Corgi.

Price, I. and Evans, L. (1993), Punctuated equilibrium: an organic model for the learning organization. *FORUM the quarterly Journal of the European Foundation for Management Development*, 93:1.

Primavesi, A. (2000), *Sacred Gaia.* London: Routledge.

Raab, J., and Milward, H.B. (2003), Dark networks as problems. *Journal of Public Administration Research and Theory*, 13:413-439.

Ramaswamy, R. (2001), Assessing availability in peer-to-peer networks. *Syslab*, June:1-2.

Rayner, A.D.M. (2003), *"Nested holeyness": the dynamic "Inclusional" geometry of natural space and boundaries*. University of Bath, retrieved 10th April 2006. http://www.bath.ac.uk/~bssadmr/inclusionality/nestedholeyness.htm

Rayner, A.D.M. (2002), Inclusionality – an immersive philosophy of environmental relationships. In A.B. Winnett (ed.), Towards and Environment Research Agenda Vol. 2, London: Macmillan.

Rayner, A.D.M. (1998), Presidential address: fountains of the forest: the interconnectedness between trees and fungi, *Mycological Research*, 102:1450-1452.

Rayner, A.D.M. (1997), *Degrees of Freedom*. London: Imperial College Press.

Rayner, A.D.M.R., Watkins, Z.R. and Beeching, J.R. (1999), Self-integration – an emerging concept from the fungal mycelium. In N.A.R Gow, G.D. Robson and G.M. Gadd, (eds.), *The Fungal Colony*. Cambridge: Cambridge University Press.

Reddy, M. J. (1979), The conduit metaphor: a case of frame conflict in our language about language. In A. Ortony, (ed.), *Metaphor and Thought*. Cambridge: Cambridge University Press.

Reffay, C. and Chanier, T. (2002), Social network analysis used for modelling collaboration in distance learning groups. In Proceedings of the 6th International Conference on Intelligent Tutoring Systems, Springer-Verlag.

Richardson, K.A. and Lissack, M. R. (2001), On the status of boundaries, both natural, and organizational: a complex systems perspective. *Emergence*, 3:32-49.

Ritchie, D. (2004), Metaphors in conversational context: toward a connectivity theory of metaphor interpretation. *Metaphor and Symbol*, 19:265-287.

Robson, C. (2002), *Real world research*. Oxford: Blackwell.

Roher, T. (1995), The cognitive science of metaphor from philosophy to neuropsychology. http://philosophy.uoregon.edu/metaphor/neurophl.htm

Rosengren, K.E. (2000), *Communication, an Introduction.* London: Sage.

Roth-Nebelsick, A., Uhl, D., Mosbrugger, V. and Kerp, H. (2001), Evolution and function of leaf venation architecture: A review. *Annals of Botany*, 87:553-566.

Ruef, M. (2002), Strong ties, weak ties and islands: structural and cultural predictors of organizational innovation. *Industrial and Corporate Change*, 11:427-449.

Ruhleder, K. (1997), Capturing complex, distributed activities: video-based interaction analysis as a component of workplace ethnography. Presented at the 1997 IFIP WG 8.2 Working Conference.

Rumelhart, D. (1979), Some Problems With the Notion of Literal Meaning. In A. Ortony (ed.), *Metaphor and Thought.* Cambridge: Cambridge University Press.

Sadock, J. (1979), Figurative Speech and Linguistics. In A. Ortony (ed.) *Metaphor and Thought.* Cambridge: Cambridge University Press.

Sagan, D. and Margulis, L. (1997), Gaia and philosophy. In L. Margulis and D. Sagan, *Slanted Truths.* New York: Copernicus.

Sagan, D., Margulis, L. and Guerrero, R.(1997), Descartes, dualism and beyond. In L. Margulis and D. Sagan, (eds.), *Slanted Truths.* New York: Copernicus.

Saussure F. de, (1966 [1916]), *Course in General Linguistics.* New York: McGraw-Hill.

Scott, J. (2003), *Social Network Analysis.* Second edition. London: Sage.

Searle, J. R. (1979), Metaphor. In A. Ortony, (ed.), *Metaphor and Thought*, Cambridge: Cambridge University Press.

Shannon, C. and Weaver, W. (1949), *The Mathematical Theory of Communication.* Urbana: University of Illinois Press.

Silverman, D. (2001), *Interpreting Qualitative Data.* London: Sage.

Silverman, D. (2000), *Doing Qualitative Research*. London, Sage.

Sonnenwald, D.H. (1996), Communication roles that support collaboration during the design process. *Design Studies*, 17:277-301.

Sporns, O., Tononi, G., and Edelman, G.M. (2000), Theoretical neuroanatomy: relating anatomical and functional connectivity in graphs and cortical connection matrices. *Cerebral Cortex*, 10:127-141.

Standifird, S.S. (2001), Conceptual bonds: network analysis as a way of understanding institutional rigidity. *Emergence*, 3:7-21.

Stern, J. (2000), *Metaphor in Context.* Cambridge, MA: MIT Press.

Stevenson, W.B. (1993), Problem solving networks in organizations: intentional design and emergent structure. *Social Science Research*, 22:92-113.

Stewart, I. (1990), *Does God Play Dice*? London: Penguin.

Tarnas, R. (1991), *The Passion of the Western Mind.* London: Pimlico.

Taylor, T.J. and Cameron, D.J. (1987), *Analysing Conversation.* Oxford: Pergamon.

Thompson, D'Arcy (1971/1917), *On Growth and Form.* Cambridge: Cambridge University Press.

Wardhaugh, R. (1985), *How Conversation Works*. Oxford: Basil Blackwell.

Volk, T. (1995), *Metapatterns.* New York: Columbia University Press.

Watts, D. J. (2004), *Six Degrees.* London: Vintage.

Watts, D.J. and Strogatz, S.H. (1998), Collective dynamics of 'small world' networks. *Nature*, 393:440-442.

Wiener, N. (1948), *Cybernetics.* Cambridge, MA: MIT Press.

Wilson, E.O. (1990), Success and Dominance in Ecosystems: the Case of the Social Insects. Oldendorf, Germany: Ecology Institute.

Appendix 1

Scheme used to transcribe video-recorded dialogue in Study 2

Adapted from an original scheme by Silverman (2001)

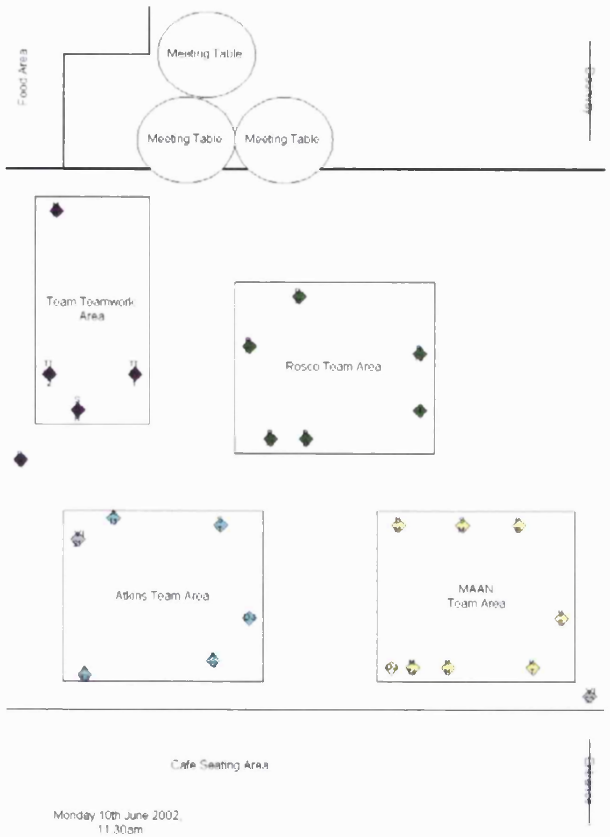
Symbol	Definition	Example
[	Left bracket indicates the point at which a current speaker's talk is overlapped by another's talk	KR: as of Wednesday, we've, we've SS: [well there's more work (to come)
=	An equals sign at the end of a line indicates no gap between that line and the next; or at the beginning of the line that there is no gap between it and the previous one	PB: yeh MW: = you know just for one row of seats.
(0.5)	A number in parenthesis indicates the elapsed time in silence in seconds	MW: cos otherwise. (2) I mean, (1) structurally
(.)	A dot in parenthesis indicates a very short gap of less than 0.5 seconds	GR: So what we solved (.) well what we realised is that anyway
----	Underscoring indicates some form of stress via pitch and/or amplitude	SS: because it was eighteen hundred
::	Colons indicate prolongation of the immediately prior sound. The length of the row of colons indicates the length of the prolongation	GR: And um: (1), because what they asked is ehm:: four
( )	Empty parentheses indicate the transcriber's inability to hear what was said. If accompanied by a figure, this indicates the number of seconds that were inaudible	SS: ( ) updated S D N F files
(word)	Parenthesized words are possible hearings	MW: (what's this?)
(( ))	Double parentheses contain author's descriptions rather than the transcriptions.	SS: ((looks round, sees him behind)) Michael?
.,?	Indicate speaker's intonation (. Is a falling intonation; , is flator slightly rising intonation	MW: Which model is that?

Table A1.1 Outline of coding scheme used to categorize the data from Study 2 (Dialogue content).

Appendix 2

Raw data and initial analysis for Study 1 - The structure of interaction networks between team members during Liveweek

On the following pages are the eighteen sets of interactions observed during Liveweek 2002 for Study 1. The original data (which were hand sketched), were converted in to computer diagrams, but in all other respects the maps are identical to the raw data. Alongside each of these maps I have also presented the social network diagrams that were generated for each of the raw data sets. These show which of the actors within the network were deemed to be *interacting* with one another (indicated by lines between them). To generate these diagrams, interactions between actors were identified on each of the eighteen raw data maps, and these interactions were used to create a eighteen corresponding separate interaction matrices on UCINET (a social network analysis software package created by Borgatti *et al*, 2002). These UCINET matrices were then converted to network diagrams using a social network drawing program, called VNA. The letters by each actor represents the actor's initials; nodes of the same colour belong to the same team.



←Figure A2.1a Map 1, which shows locations of actors at Liveweek on Monday 10th June at 11.30am.

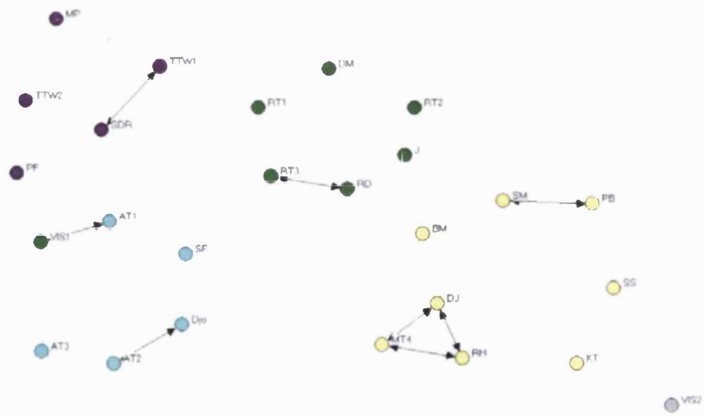
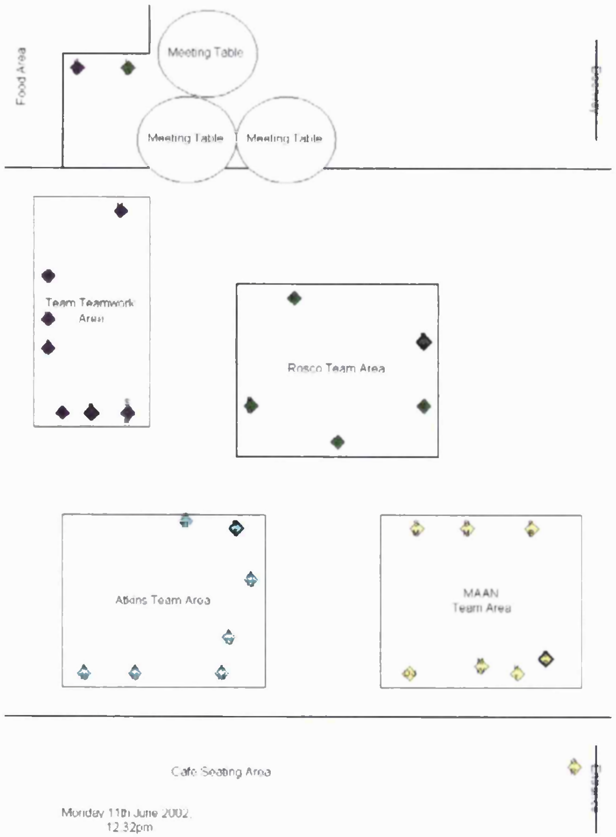


Figure A2.1b Social network map representing the data from observation map 1 (Figure A2.1a).



←Figure A2.2a Map 2, which shows locations of actors at Liveweek on Monday 10th June at 12.32pm.

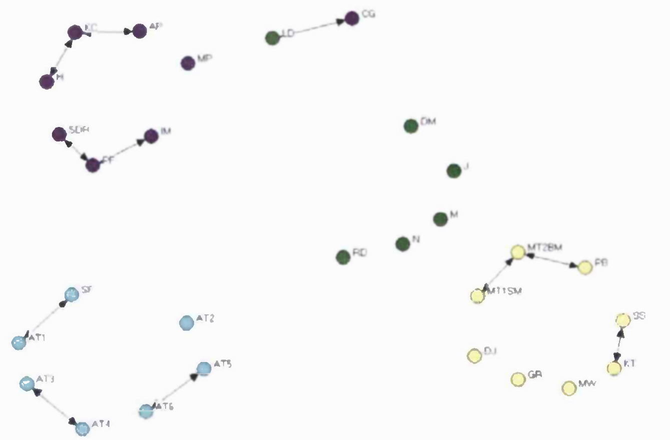
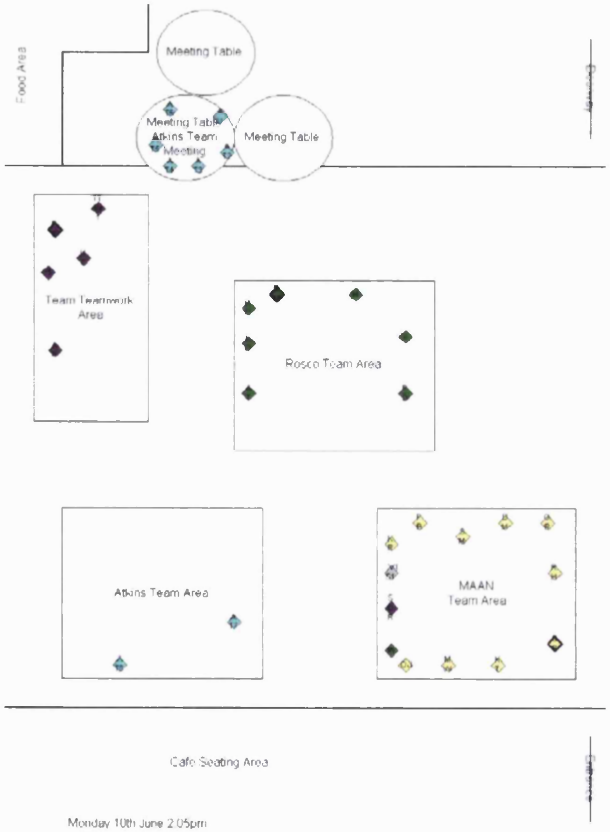


Figure A2.2b Social network map representing the data from observation map 2 (Figure A2.2a).



←Figure A2.3a Map 3, which shows locations of actors at Liveweek on Monday 10th June at 2.05pm.

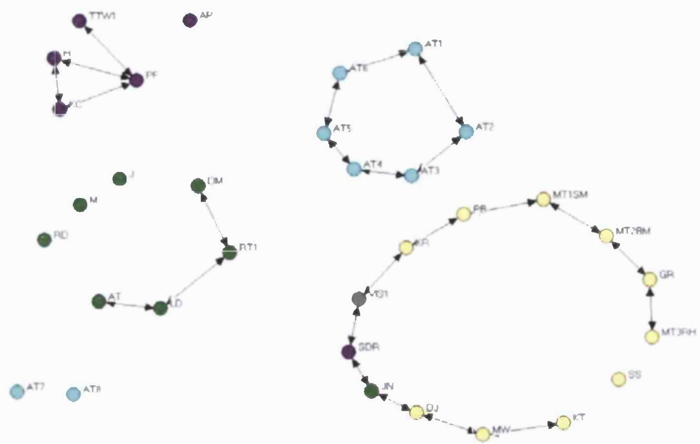
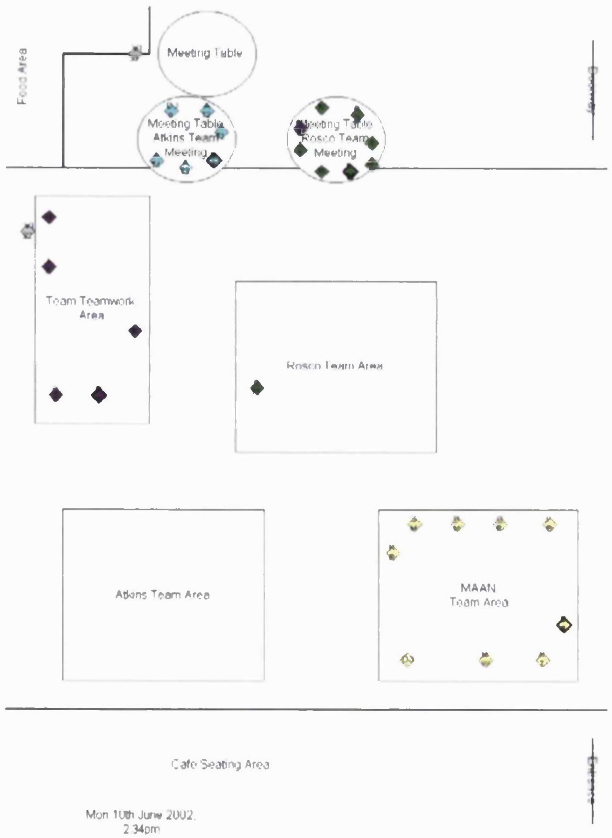


Figure A2.3b Social network map representing the data from observation map 3 (Figure A2.3a).



←Figure A2.4a Map 4, which shows locations of actors at Liveweek on Monday 10th June at 2.34pm.

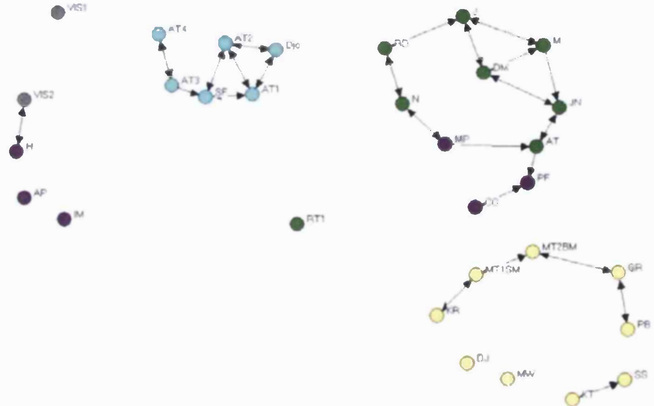
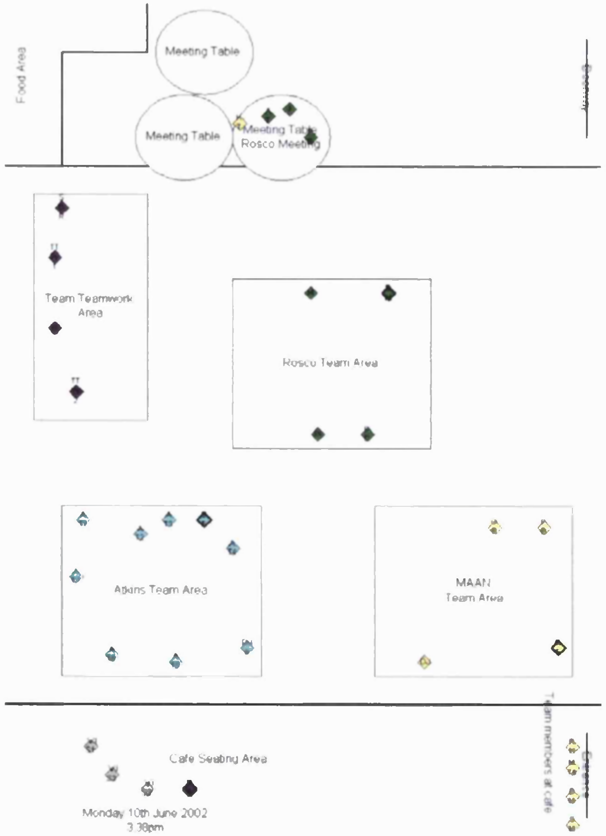


Figure A2.4b Social network map representing the data from observation map 4 (Figure A2.4a).



←Figure A2.5a Map 5, which shows locations of actors at Liveweek on Monday 10th June at 3.38pm.

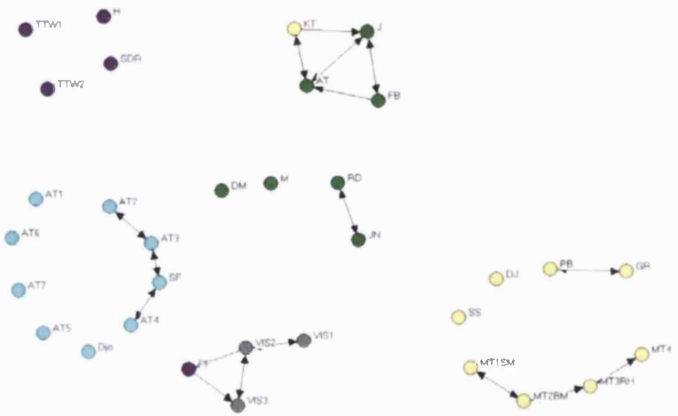
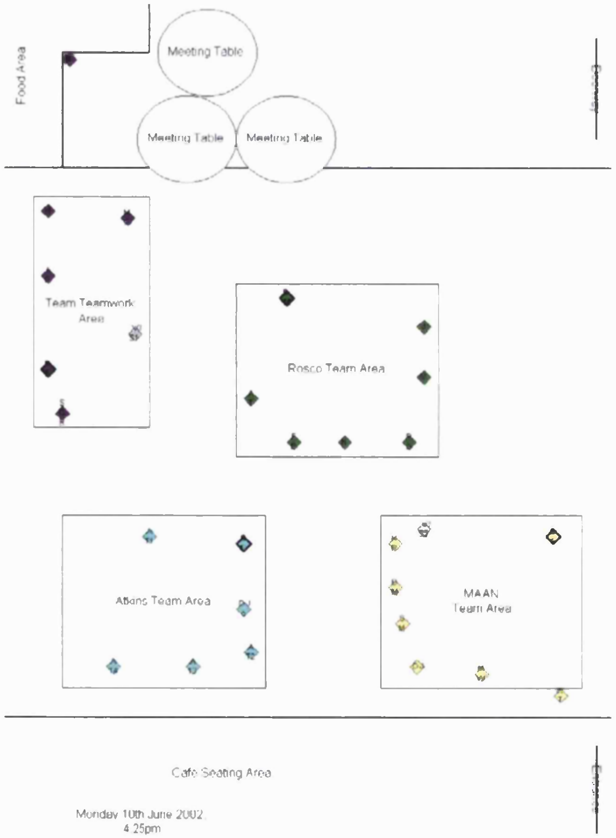


Figure A2.5b Social network map representing the data from observation map 5 (Figure A2.5a).



←Figure A2.6a Map 6, which shows locations of actors at Liveweek on Monday 10[th] June at 4.25pm.

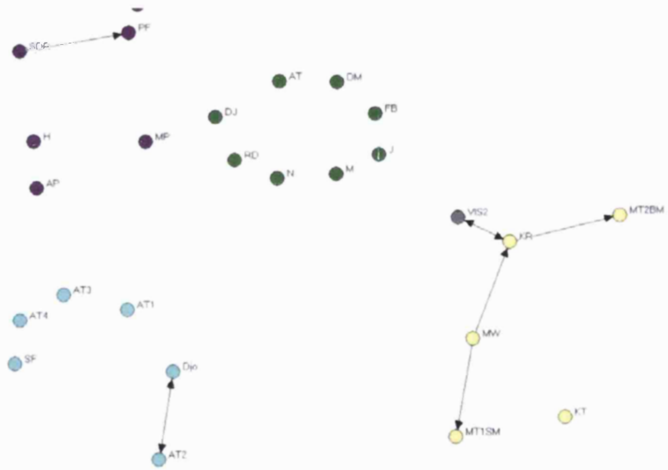
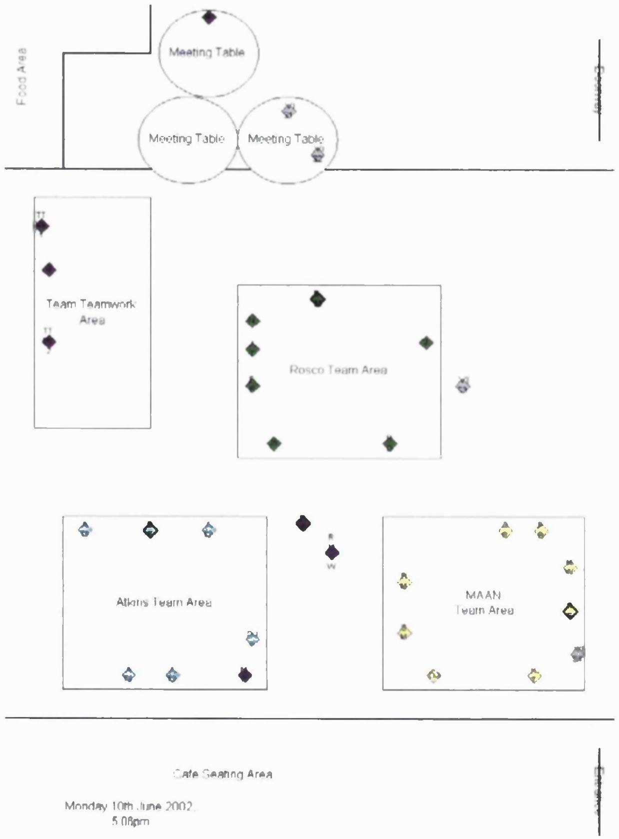


Figure A2.6b Social network map representing the data from observation map 6 (Figure A2.6a).



←Figure A2.7a Map 7, which shows locations of actors at Liveweek on Monday 10th June at 5.06pm.

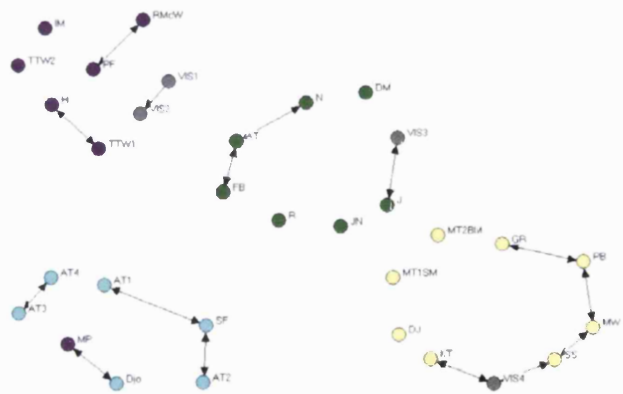
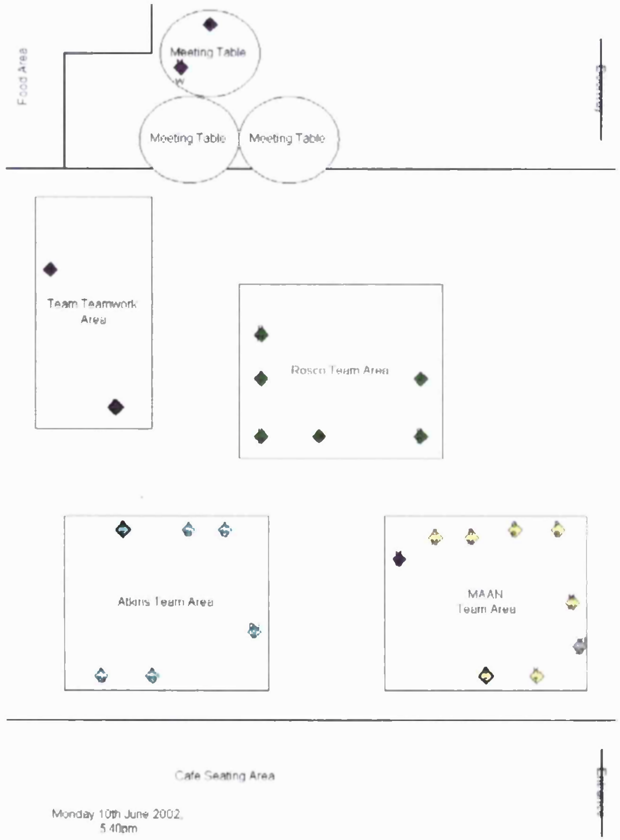


Figure A2.7b Social network map representing the data from observation map 7 (Figure A2.7a).



←Figure A2.8a Map 8, which shows locations of actors at Liveweek on Monday 10th June at 5.41am.

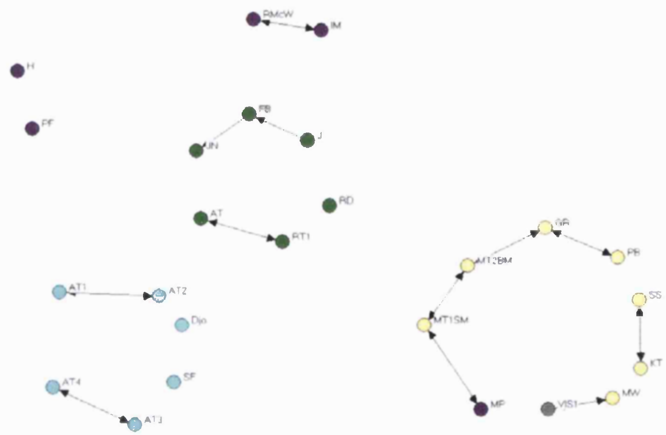
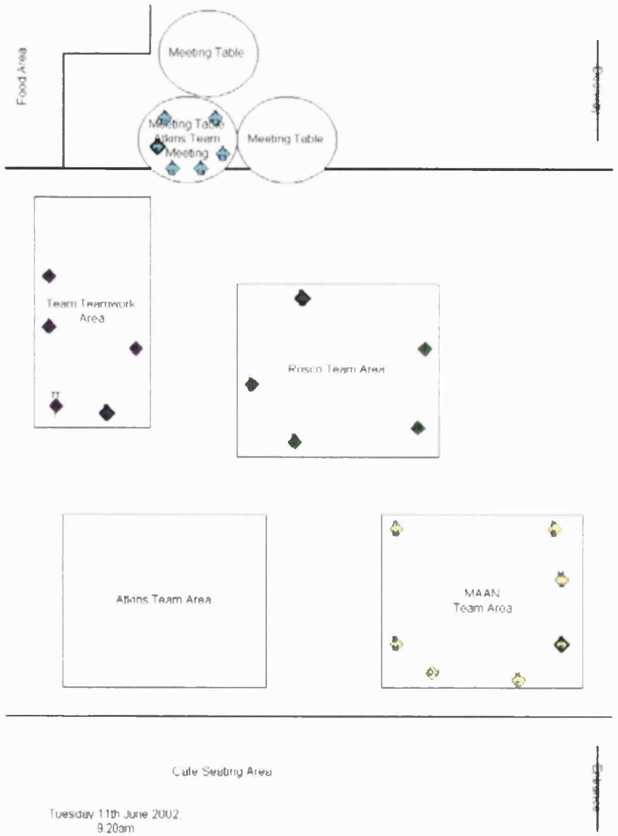


Figure A2.8b Social network map representing the data from observation map 8 (Figure A2.8a).



←Figure A2.9a Map 9, which shows locations of actors at Liveweek on Tuesday 11th June at 9.20am.

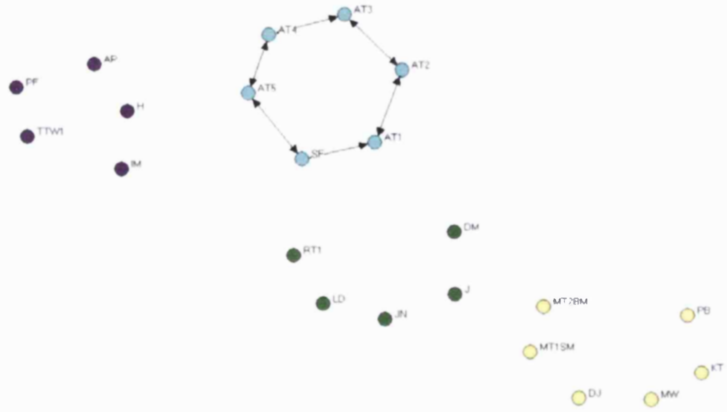
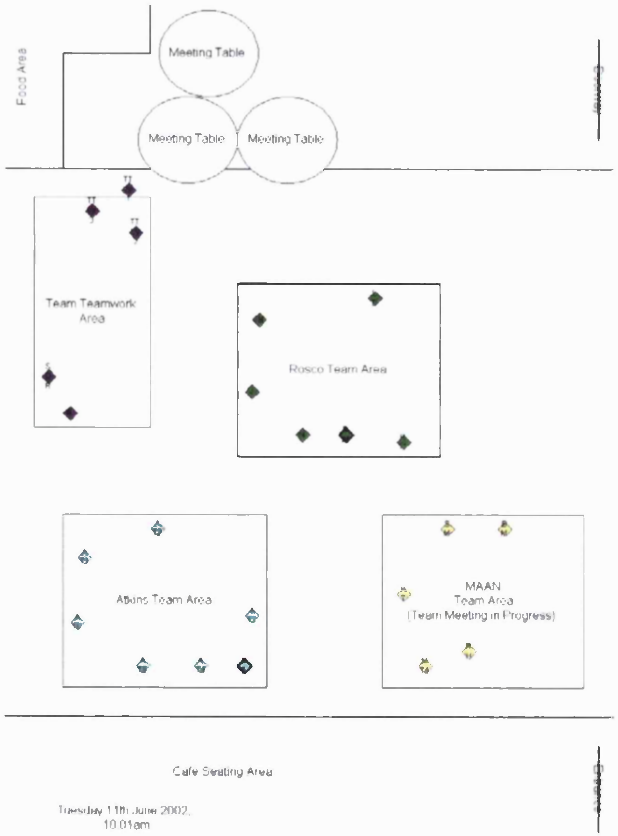


Figure A2.9b Social network map representing the data from observation map 9 (Figure A2.9a).



←Figure A2.10a Map 10, which shows locations of actors at Liveweek on Tuesday 11th June at 10.01am.

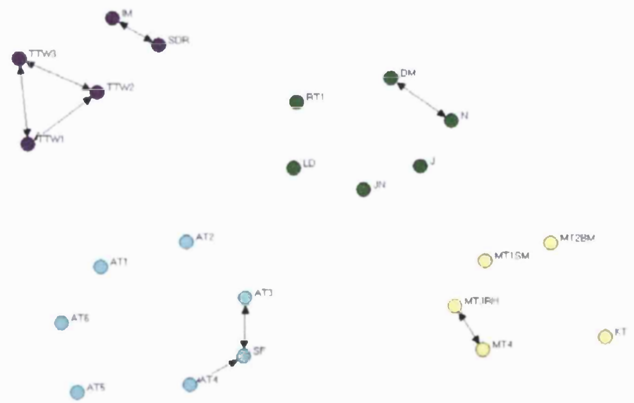
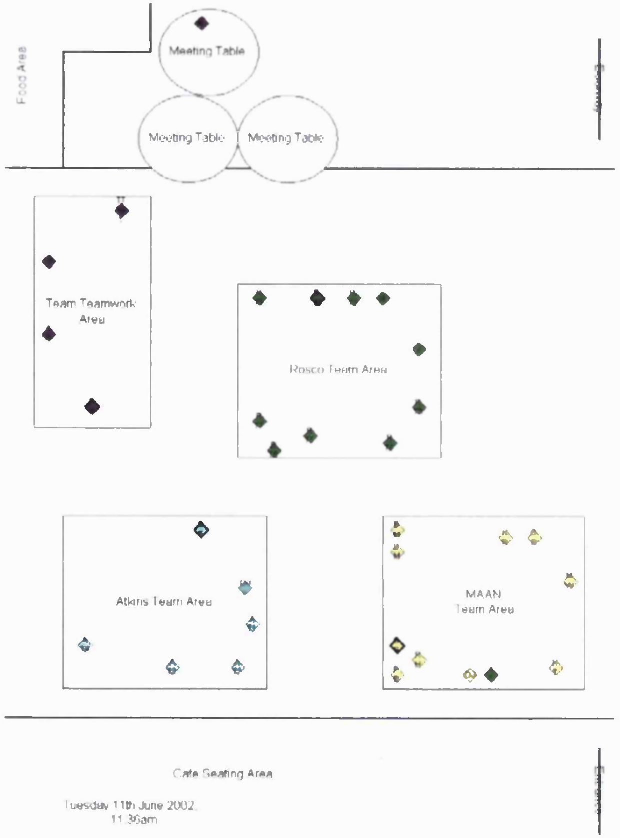


Figure A2.10b Social network map representing the data from observation map 1 (Figure A2.10a).



←Figure A2.11a Map 11, which shows locations of actors at Liveweek on Tuesday 11th June at 11.36am.

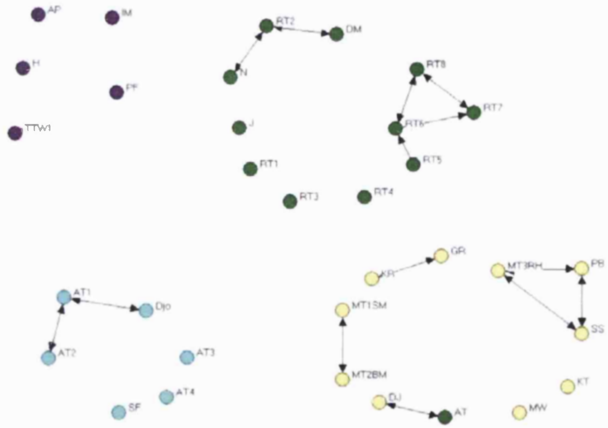
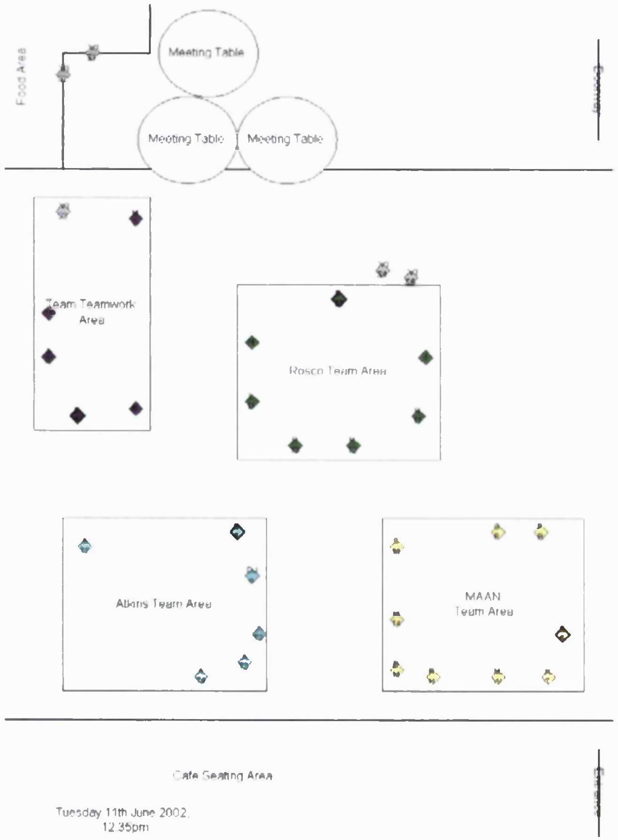


Figure A2.11b Social network map representing the data from observation map 11 (Figure A2.11a).



←Figure A2.12a Map 12, which shows locations of actors at Liveweek on Tuesday 11th June at 12.35pm.

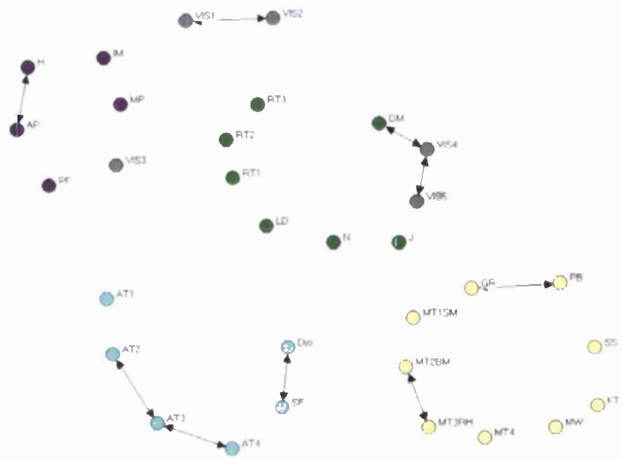
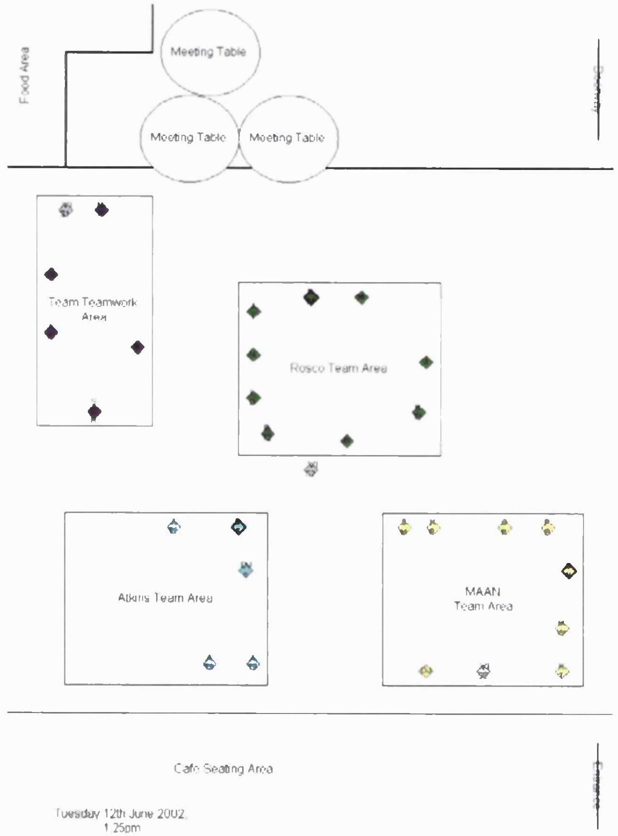


Figure A2.12b Social network map representing the data from observation map 12 (Figure A2.12a).



←Figure A2.13a Map 13, which shows locations of actors at Liveweek on Tuesday 11th June at 1.25pm.

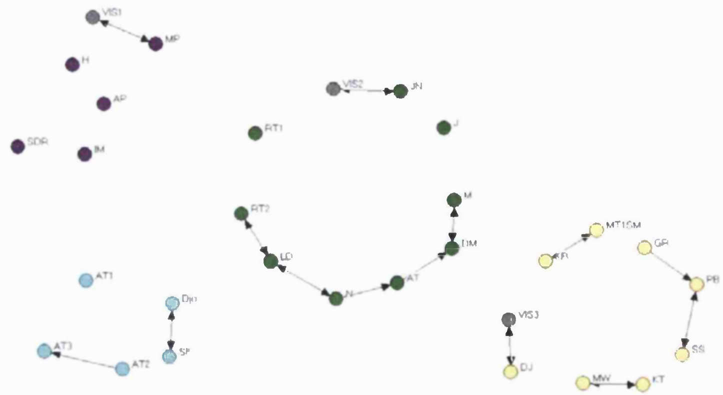
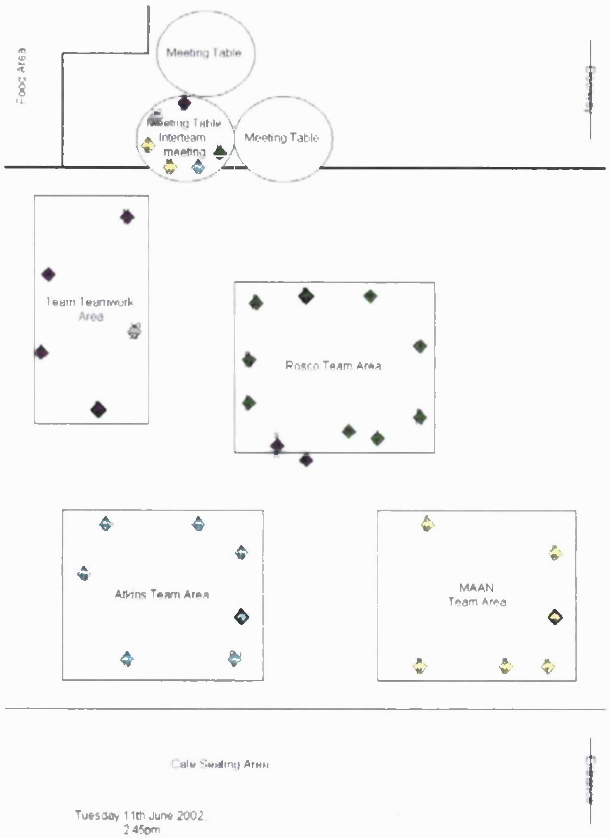


Figure A2.13b Social network map representing the data from observation map 13 (Figure A2.13a).



←Figure A2.14a Map 14, which shows locations of actors at Liveweek on Tuesday 11th June at 2.45pm.

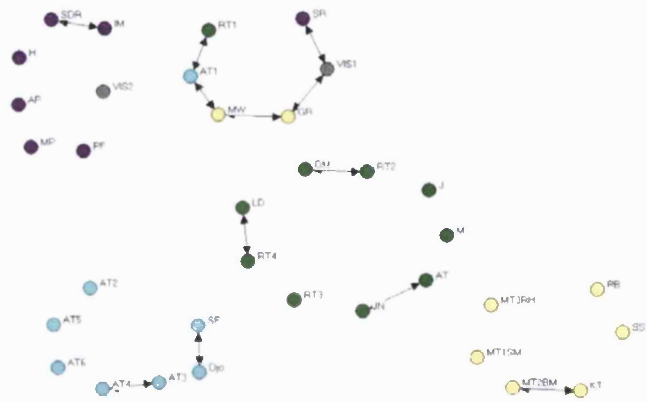
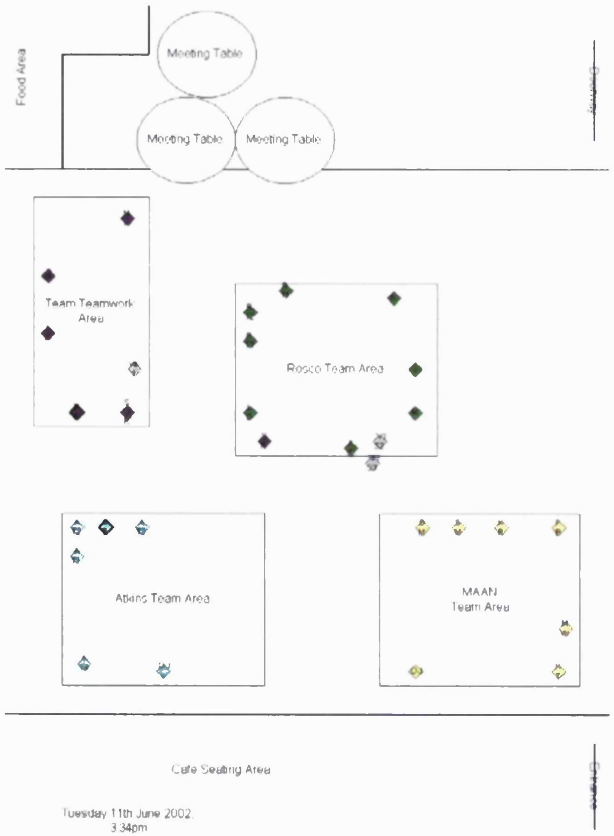


Figure A2.14b Social network map representing the data from observation map 14 (Figure A2.14a).



←Figure A2.15a Map 15, which shows locations of actors at Liveweek on Tuesday 11th June at 3.34pm.

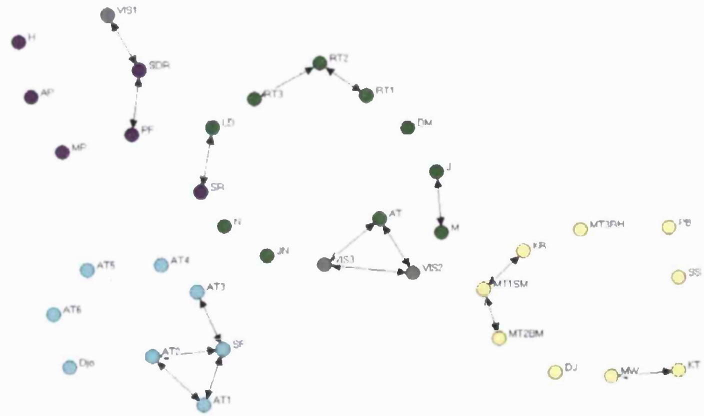
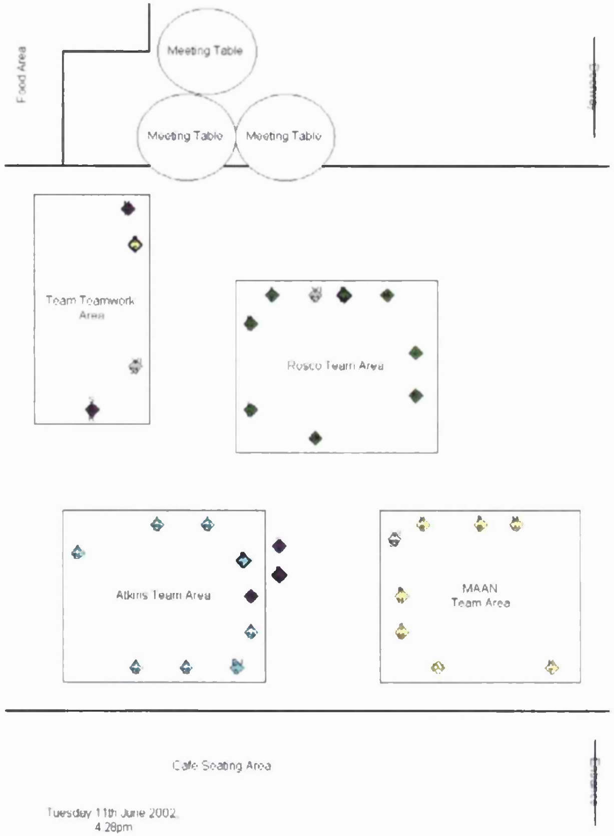


Figure A2.15b Social network map representing the data from observation map 15 (Figure A2.15a).



←Figure A2.16a Map 16, which shows locations of actors at Liveweek on Tuesday 11th June at 4.28pm.

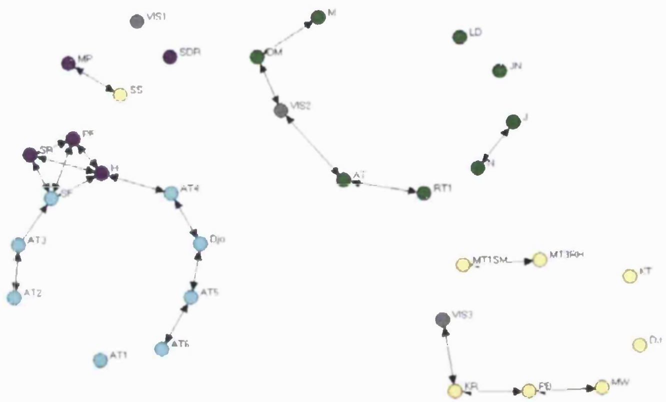
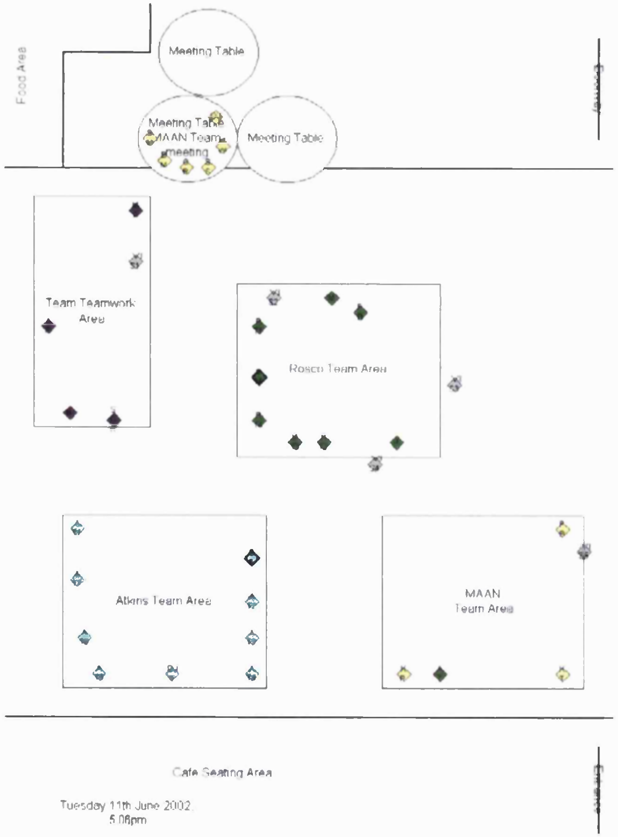


Figure A2.16b Social network map representing the data from observation map 16 (Figure A2.16a).



←Figure A2.17a Map 17, which shows locations of actors at Liveweek on Tuesday 11th June at 5.06pm.

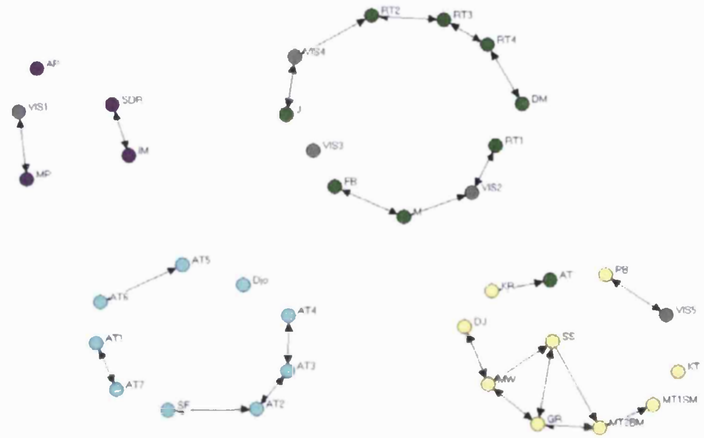
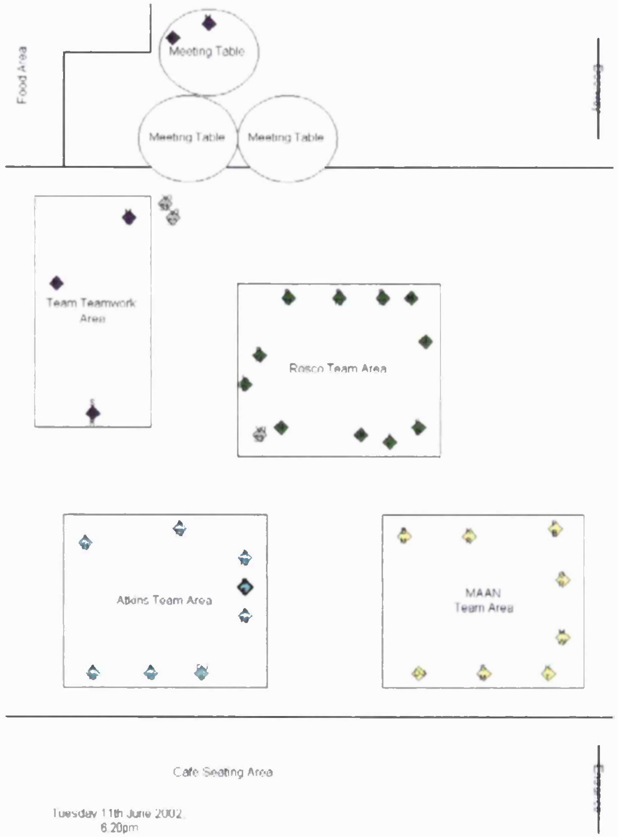


Figure A2.17b Social network map representing the data from observation map 17 (Figure A2.17a).



←Figure A2.18a Map 18, which shows locations of actors at Liveweek on Tuesday 11th June at 6.20pm.

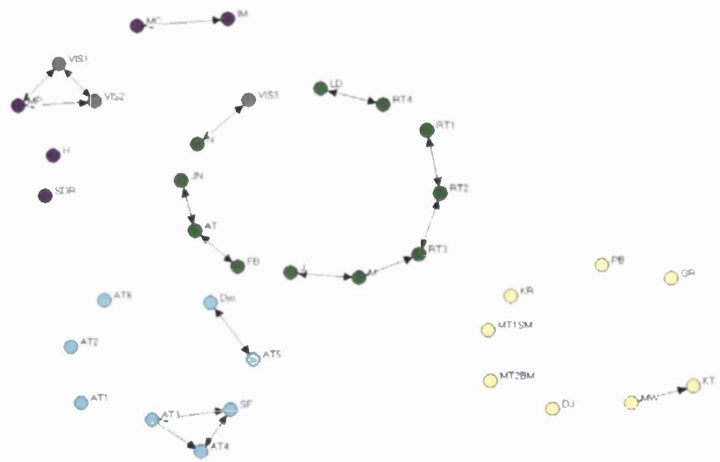


Figure A2.18b Social network map representing the data from observation map 18 (Figure A2.18a).

Appendix 3

Excerpt of Transcribed and Coded Content Data from Study 2 (Dialogue Study)

This excerpt is intended to provide and example of the transcribed and coded content data. The convention used to transcribe the data was derived from Silverman (2001) (see Appendix 1 for details). The coding scheme was created specifically for this study, as described in Chapter 9. The letters in bold at the start of each utterance indicate the coding categories applied to that statement, while the letters in italics at the start of each statement. Some utterances have more than one coding letter; this is because several kinds of utterance were deemed to be represented in the utterance.

An outline of the final coding scheme is presented in Table A3.1. For full details of the coding scheme, please refer to Chapter 9.

Code	Type of utterance
A	Suggesting a new idea
B	Providing skilled advice (positive)
C	Providing skilled advice (negative)
D	Organizing the process
E	Organizing the people
F	Stating a problem
G	Giving positive feedback
H	Giving negative feedback
I	Contextualising statement
J	Query
K	Reporting a past action
L	Reporting an intended action
M	Explaining the design
N	Social exchange
X	Not categorized
1	Pointing something out on a computer screen
2	Sketching and/or pointing something out on paper

Table A3.1 Outline of coding scheme used to categorize the data from Study 2 (Dialogue content).

Data recorded on videotape on Monday 10th June 2002 during Teamwork 2002, at the RIBA, Portland Place, London

Time: 10.59am

Team Meeting – team members seated around a circular table in the team meeting area

E D *SS*: Right he knows about it. (1) I think I've been round to every to show the setup of the: folders (.) so basically everyone knows where it's <saved>. Um for the knowledge capture and (0.5) preparation for the presentation (.) if there's anything interesting you're doing, just keep saving screenshots (.) write things down. (2) And there's a form for the knowledge capture, (1) if it's got to do with your discipline, just put it in your discipline, (.) if it's a team thing (2), I think for most people it will just be a discipline issue. And if you could all save if under your name, your initials, (.) and actually an adequate name that sa:ys what's in the document (.) instead of just document ( ), (1) and that will help with finding it later. (1) I know it's annoying but if we do it as we go along (.) it will help a lot for the presentation later. (2) Right.

X *KR*: ()

X *SS*: What?

J *KR*: () as far as today's concerned (or is it just tomorrow)

D *SS*: Yeah, today or tomorrow (3). Because I think we need to get everything off the server by tomorrow night, (0.5) because we won't have access to it (1) for Wednes (.) for Wednesday and Thursday. (1) So the less work we have (.) to just get it off the server (2).

K F E *SS*: Right (2). This is Kieran's (1.5) design (4). What they basically asked us to do (.) is increase the (.) um rows from the balconies? (1.5) And (we first) came up with the idea of (.) um adding (0.5) two extra rows (1.0) on all levels (0.5). But when we: initially discussed it (.) we said (.) it's quite impossible because (.) the people on top (.) you know, the back people won't be able to see anything? (1) So we came up with um (2.5) this arrangement (.) and we're saying put an extra row on the bottom (1) balcony. (1) Keep two, (.) two (.) and add an extra row in the top. (1) Because we basically need to keep the same (.) number of seats (1), but we have to check probably (put more on the) the same (number of) balconies and rearrange somehow so that we have the same number of seats. (1) So that's as far as we got (1.5). We have to come up with a solution now (.) <or or> at least a strategy, (0.5) so each of the disciplines could set off and start doing (1) that.

(3)

B *MO*: (So we push it up) ( )

C *SS*: But then the structure doesn't (1) change that much apart from the columns

C *MO*: yeah but ( ) (the other gentleman showed us)

C *SS*: But you would have to have more capacity then

C *MO*: I uh ( ) it's the same number of seats

B *GR*: Yeh (this is too)

X *MO*: [( )

F *SS*: [(It's the seats on the balconies)

X *PB*: [It would be quite ( ) heheh

B *MO*: But then it couldn't be less than twenty ( )meters wide

X *SS*: Say again?

X *MO*: Less than twenty-four meters wide

J *GR*: Less than twenty four meters?

(2)

B *MO*: Because (supposing) the vent doesn't work very well

X *SS*: ( )

C *MO*: I don't think you are, it's about eighteen meters

B *MW*: Yeah round about ( )

X *GR*: You just (.) you just

J *MO*: (about how many more seats you're putting in)

X *SS*: How many?

F *GR*: That's (.) what we want now to sort out, we need to count the seats and see how many we put in? (0.5) And how ( ).

F *SS*: Cos at the moment, (1) or what we haven't designed yet, hehe=

X *PB*: Heheheh

F *SS*: = is ehm (0.5) we actually have another (.) balcony above these revolving doors? (2) On each level. (1) So what we need to check is (.) how many seats

(5).

E *SS*: But I think there is almost enough information (0.5) for everyone to start ( ) to look into their discipline

X *PB*: ( )

B F *GR*: ( ) because we anyway increase at least one more seat each side. (0.5) Or would you say ( ). Because that's one of the things (I have a question on)? (0.5) Is that if we put, (.) if we add at least one more row (0.5) then it becomes too narrow (.) this area? And if we should anyway increase the width of ( )
F *PB*: ( ) when we add one more uh ( )
B *SS*: If we had more people on the balcony and less people ( )
X *PB*: That's true ( )
J *MW*: ( ) performance space
X *GR*: Yeah performance space
B *GR*: Because anyway what we have to think of is the proportion of the stage also because (0.5) the stage should be between six to eight metres er deep ( ) and so if it's twelve or thirteen it's fine. (3) And so.
J *PB*: What's the step we:uh
B *SS*: [So we have to increase our::
F *PB*: [Yeah that's what er:: we have to figure out (2), and er: (don't forget we have) to figure how to add that extra row (when we take out these two) sections (.) as well
(2)
B *KR*: (you avoid a lot of problems if) ((inaudible))
X *PB*: Yeah
X *GR*: Yeah (2)
X *PB*: Ok we can just
C *GR*: [I think we should do as much as we can not to change (overall)
(1)
X *KR*: ((inaudible))
X *GR*: .pt because also I think that er:
(1)
B 2 *PB*: Maybe it's better to: um (0.5) ((leans over to point out with pencil on drawing in centre of table)) instead of having two seats there
(1.5)
B 2 *SS*: You know (.) that it's not a problem to extend the building that way (1) because it's repetiteeve (.) repetitive (.) that way (0.5) so we could make it (0.5)
B *MW*: don't worry too much about the structures (0.5) (see we could) (0.5)
D *SS*: But you can (.) you know (0.5) to make it easier you know=
X *MW*: Yep

D 2 *SS*: =it's (.) if they need to increase it (.) it would be easier to increase it that way (.) structurewise (.) than that way(.) because that way it doesn't matter we just copy and (paste)
X *PB*: [((inaudible))
X *SS*: no
J *PB*: but if we make it wider, would that be (a problem)?
B *GR*: [Yes it's (possible)
C *MW*: [wider is (0.5) a lot more calculations but it's not impossible you know it's just ( )
X *PB*: [I mean if
(1)
X *SM*: (we did)
X *SS*: (One week)
D *SS*: No I know (.) You can do everything but it starts to be more expensive
X *SM*: ((inaudible))
X *SS*: Yeh
X *KR*: ((inaudible))
X *SS*: Yeh
X *KR*: ((inaudible))
X *GR*: Yeh
X *SS*: Yeh
D *SS*: So it would make sense to increase it that way
B *KR*: One thing (.) you know ((inaudible))
X *GR*: Yeh it is much better
X *KR*: ((inaudible))
X *SS*: Right
(2)
E *SS*: So structurewise (0.5) you'll (.)you check if we need another bay (.) in that direction (1) But we don't need you know (.) you just tell us (.) what it is (1.5). Ok (0.5). And structurewise we have to check (0.5) how we're going to solve
J *GR*: [(I have a doubt actually) (.) um ( ) asked us to (0.5) to add two extra rows. (0.5) Do they mean (above or in front)?
K *SS*: No. (.) When we told them that (.) you know, it's impossible to do two extra on
X *GR*: [(ok)

D *SS*: (.), then then they agreed to say (.) it's not to make life difficult (.) we just want to make a change (1) and if you say it's more (0.5) reasonable to (perfect the steel) (then) ((inaudible))=

J *SM*: = I suppose ehm ((inaudible))

B *SS*: At the moment there's um (0.5) a moment (.) it's just cantilevering out from ( )

C *MW*: [(but that's not to scale)

X 2 *PB*: ((stands and leans toward drawing in centre of table pointing something out)) ((inaudible))

B *SS*: because it was eighteen hundred (2) it's eighteen hundred

C *MW*: You really need to ( ) of the prop

C *SS*: Because I think the eighteen hundred was just about right (for the end connections) (1) but decreasing it

End transcription at 11.08am